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ABSTRACT

Although computer graphics professionals usually consider only technical graphic design issues, recent improvements may make the only limiting design factors the user's purpose, imagination, style, and taste rather than computer hardware or software technology. Computer graphics designers can be helped to avoid pitfalls by understanding the visual processing functions of the brain and the way humans perceive graphs. Graphics should be designed to enhance analysis by the right brain to avoid misleading and confusing visual effects. For example, unnecessary labeling and grids and poorly chosen line weight distract the right brain's visual perception. In this case, visual impact may be enhanced by minor layout changes. Although technical problems may still affect adaptation of information to a display medium, computer graphics designers should learn to study visual effects and have a computer-based tool available to allow experimentation with such effects during the initial design stages. The points discussed in this paper are illustrated with numerous examples of different types of graph designs, and their implications are discussed. (LMM)

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DESIGNING A GOOD GRAPH

BY

Anders Vinberg

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Designing a Good Graph

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ABSTRACT

The software and hardware technology has recently come far enough that the limiting factor in graphical quality may be the style and taste of the user. Many of the rules of thumb of good graphics are analyzed in terms of modern theories on brain function, the influence of previous experience on the part of the viewer, and modern computer graphics technology. This leads to a need for graphics systems that allow a user to study the visual impact of his graph.

That graphics is a very effective form of communication is now generally recognized - and indeed the reason for this conference. However, there is little understanding of issues like, Why is graphics effective? Why are some graphs successful, and others not? Which features work well? Which features work well together? Why, basically, is one picture worth a thousand words (or, in Carl Machover's words, why is one word worth 1E-3 graph)?

We must recognize that graphical representation is not an abstract thing, nor is it an absolute science. It is a tool, a tool that we can wield to achieve certain results. Leslie Siegal has phrased it well [Sieg]:

> "A bar chart is nothing but the skeleton of a story until the designer decides that it's a message that should be shouted, or whispered, or giggled, or just admitted."

Like most tools, this one must be wielded well to create the results we desire. Graphic representation is a sharp and powerful tool - and as with most sharp tools, the unskilled operator may cause more damage than benefit.

Graphic representation is a multifaceted tool, offering many opportunities for tailoring a graph to give a specific impression - but also for messing up. We can play with line charts, bar charts, pie charts, maps, perspective pictures, block diagrams; with logarithmic and other non-linear transformations; mathematical interpolations and regressions; shading, color, grayscales, textures; annotation in various typefonts, sizes, and styles; arrows, stars, and untold other gadgets. Perhaps it isn't surprising that the user faced with all these options fouls up more often than not. After all, "a man with one clock knows what time it is - a man with two clocks isn't really sure."

Note: This paper was typeset entirely by computer. Except where indicated otherwise, all the illustrations were generated with the DISSPLA® or TELLAGRAF® software systems, products of Integrated Software Systems Corporation.

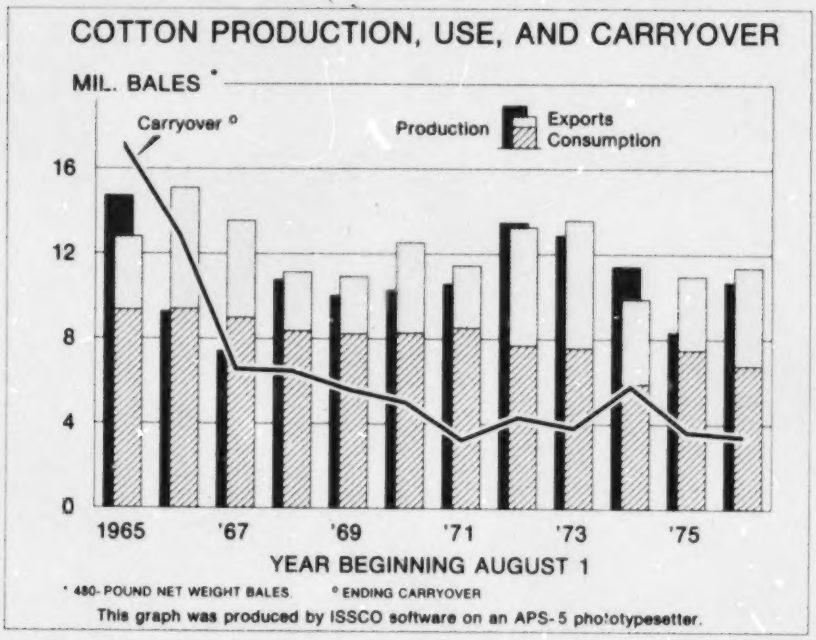

Figure 1. Graph designed by a graphic artist (but generated by computer)

Why is the graph designed by an artist so much "better", so much more visually pleasing, than the graph designed by the computer specialist? What do they do, the artistic wizards, that cause us to catch our breaths, buy something, sell something, believe something, or just exclaim, "That's neat - why didn't I think of that?" How do we write a user's manual for our sharp tool, one that makes artists of us all?

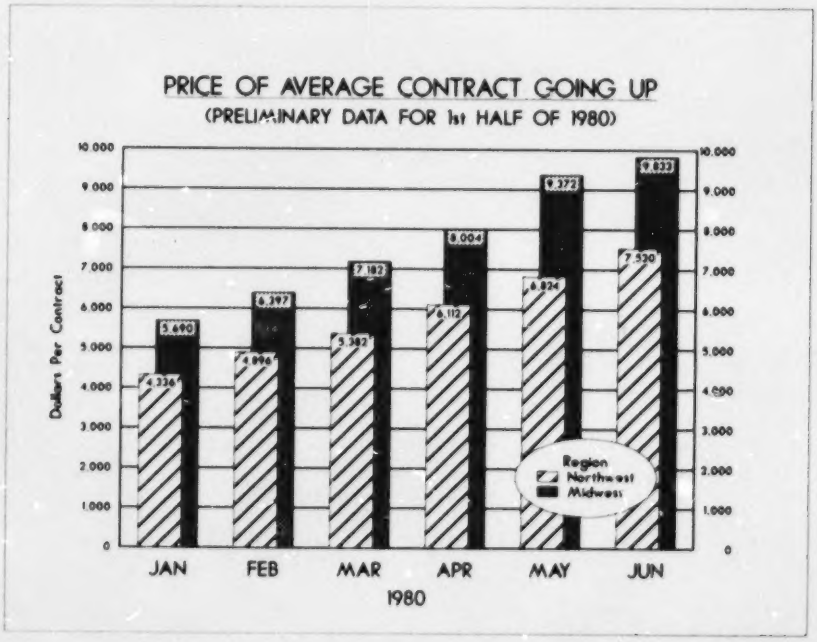

Figure 2. Graph designed by a computer graphics person (the author)

As an illustration of the subtlety of the problems, consider the following sequence of graphs. They were designed to illustrate various levels of graphic sophistication. While designing this sequence, the author originally created the first three graphs. Completely unexpectedly, the second graph with line smoothing became visually weaker than the original "ugly" graph. Since the line no longer passes through the data symbols, it appears visually lighter than the original squiggly line. We must increase the line weight, as in the last figure, to preserve the visual weight and get the benefits of the otherwise increased quality.

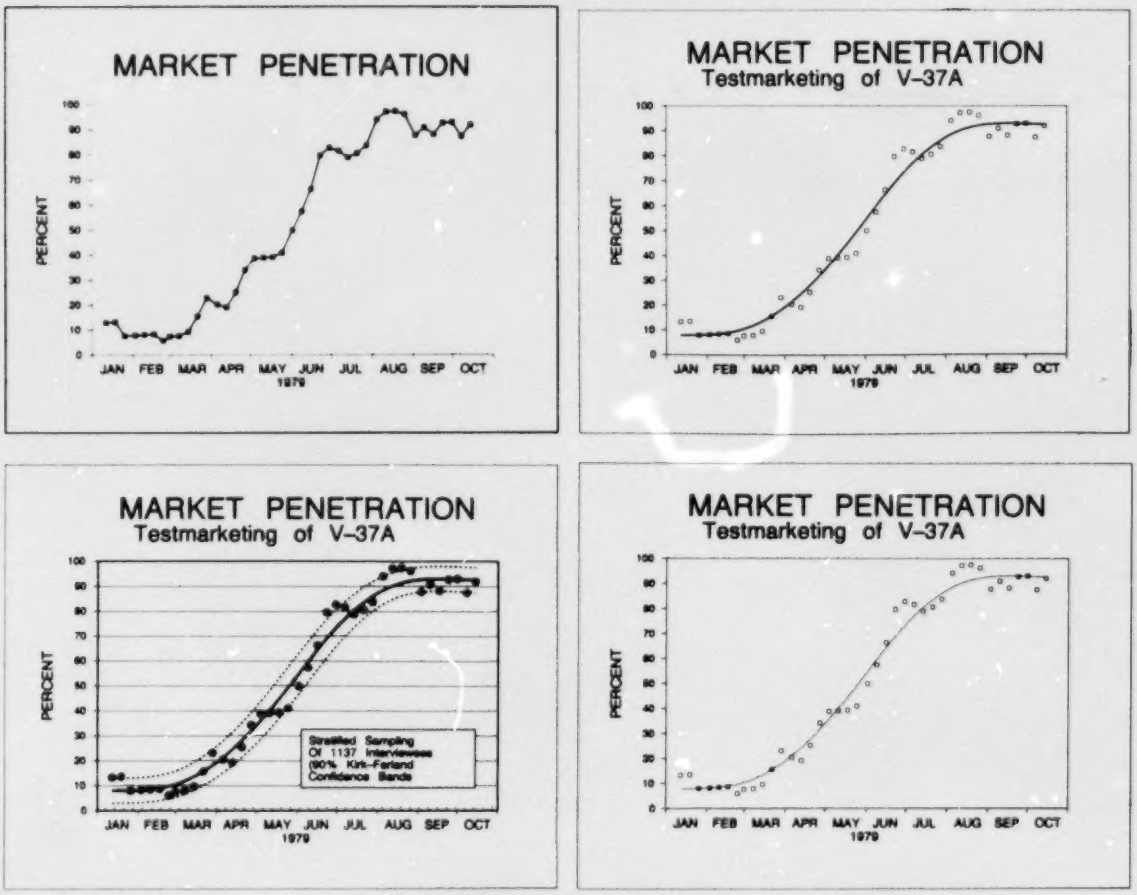

Figure 3. Progressive sophistication sequence

This was an unexpected effect that fooled an experienced user. And most distressing to us computer graphics professionals, when the graphs were reproduced on another output device, the effect went away - the initial graph was just as effective as the final one. We must tackle not only artistic problems, but technical ones as well - and perhaps hardest of all, the interaction between the two worlds.

It should be stressed here that the most important aspects of choosing the right graph are not technical - neither computer technical, nor graphically technical. The two graphs below are technically equally good, and both show all the information clearly and honestly. Which one is best can be decided only with knowledge of the intent of the report, presentation, or article where the graph is used. The bar chart on the right places greater emphasis on the amount of money accumulated in the federal deficit over the years - the choice of graph should perhaps include political considerations.

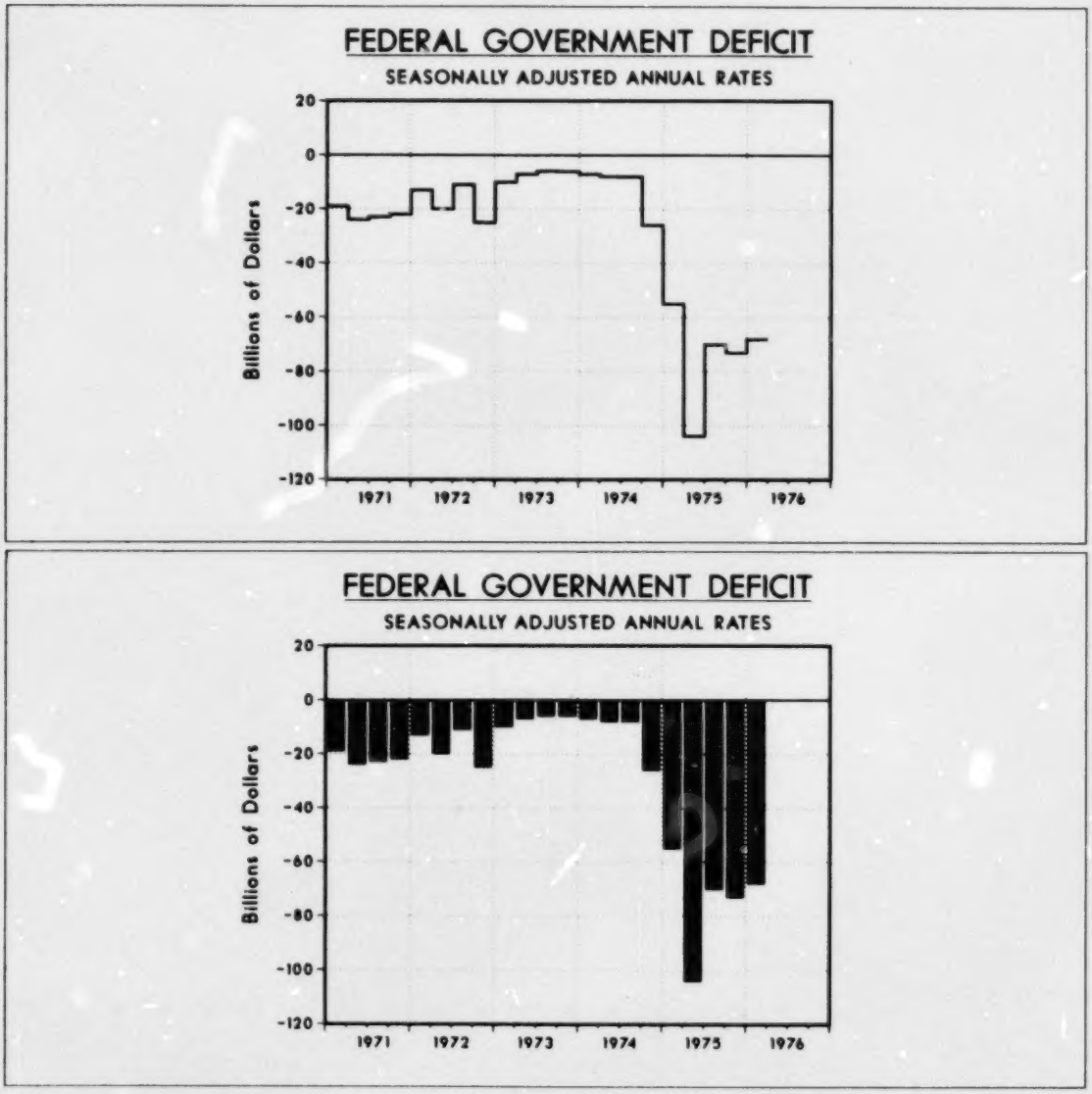

Figure 4. Two equally good graphs with the same information but with different messages

THE PROGRESSING TECHNOLOGY OF COMPUTER GRAPHICS

Computer graphics professionals rarely address issues like these. All attempts to computerize graphics usually presents sufficient technical difficulties to keep us preoccupied with the most basic problems. However, recent developments have brought us to the point where the limiting factor may no longer be either hardware or software technology, but rather the imagination, taste, and sense of style of the user. A quarter century after the first computer generated graphs we can finally offer tools that a reputable graphic artist doesn't immediately reject as ridiculous.

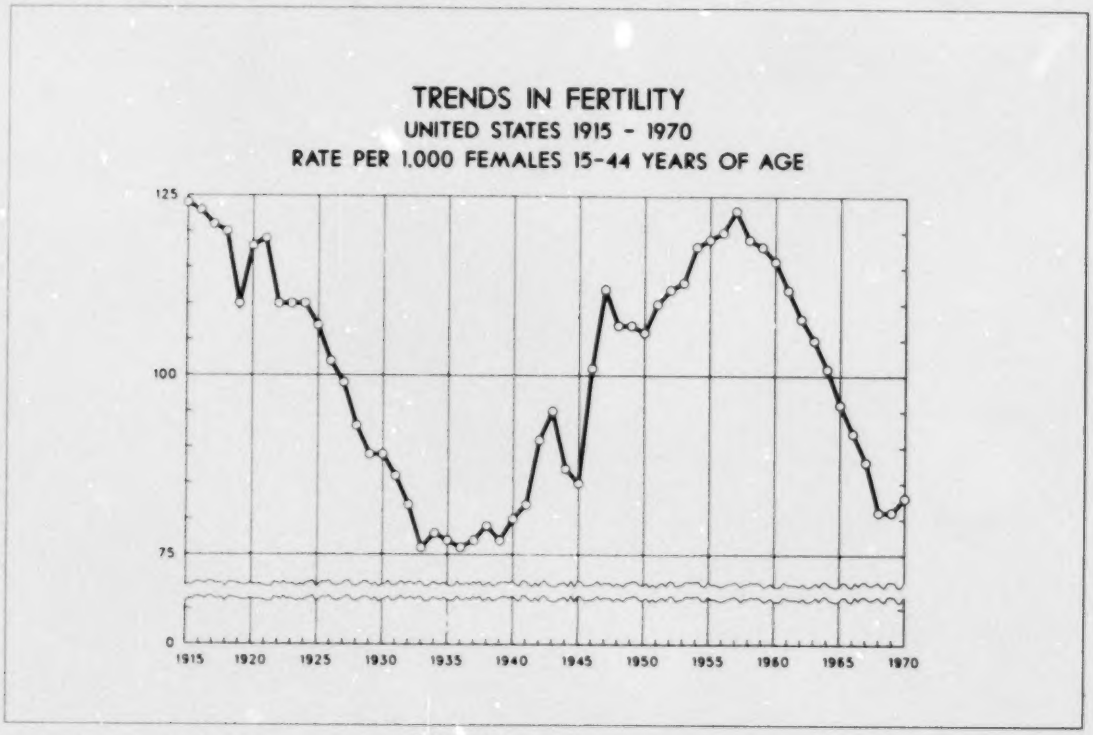

Figure 5. Example of current graphics technology

We may not have come all the way yet - some things done as a matter of course manually still baffles computer graphics technology - but many artists now accept computer graphics as one tool among many, a tool with advantages and disadvantages.

This must obviously be the goal. In the words of Larry Cornish, we will not have achieved maturity until the word "computer" is dropped from the phrase "computer graphics"; just as no one talks of a computer engineer or a computer mathematician, we shouldn't consider computer graphics users a breed apart from other graphic artists.

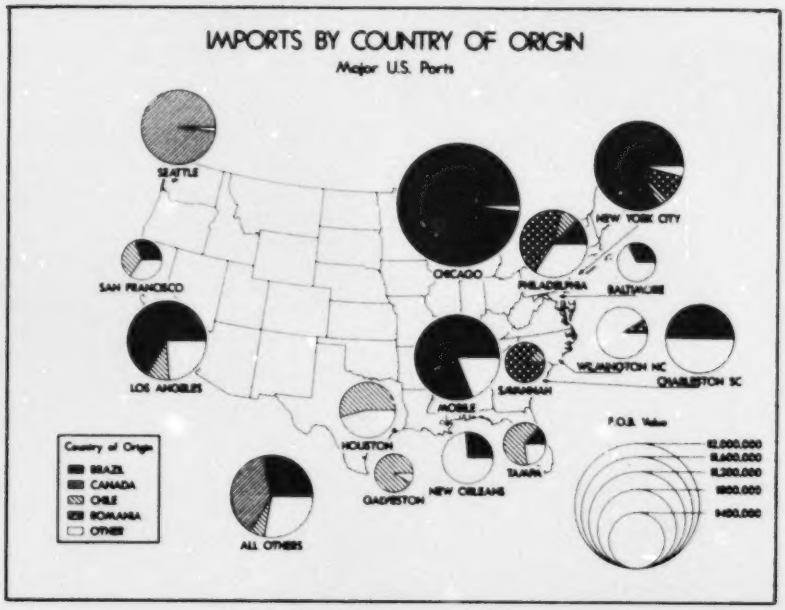

Figure 6. Current state of the art of graphic technology

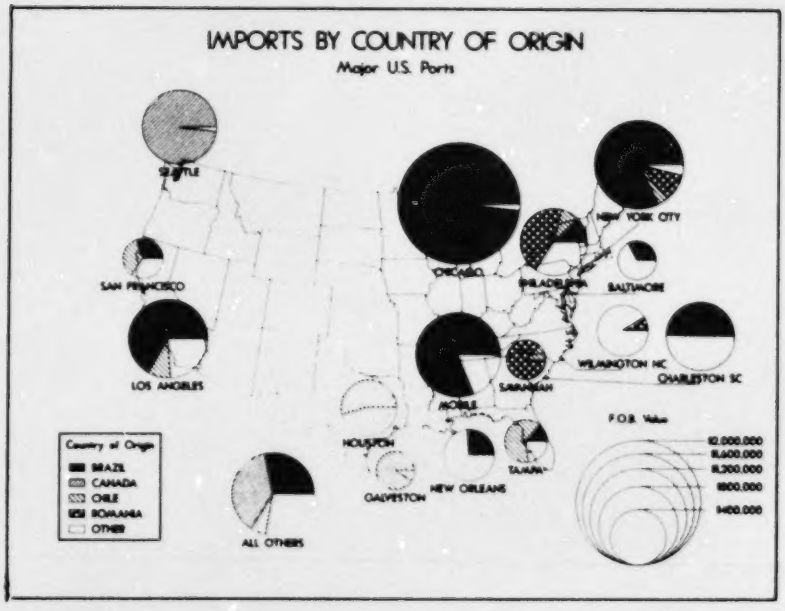

Figure 7. Last year's graph

Comparing an artist's graph with a computer generated copy, we see that the differences are minor, and not unequivocally to the artist's advantage.

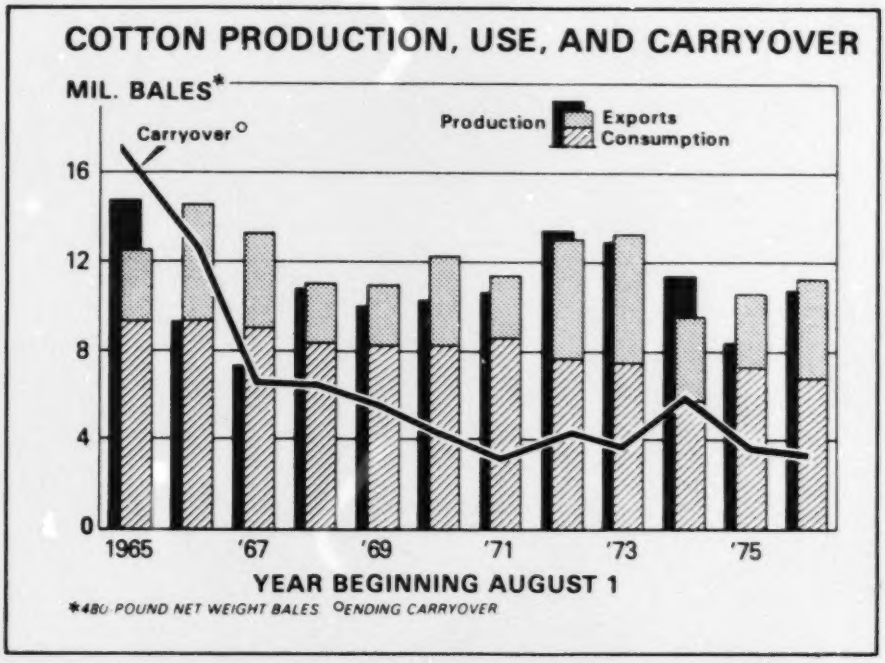

Figure 8. Manually created graph (reproduced from [Schm] by permission)

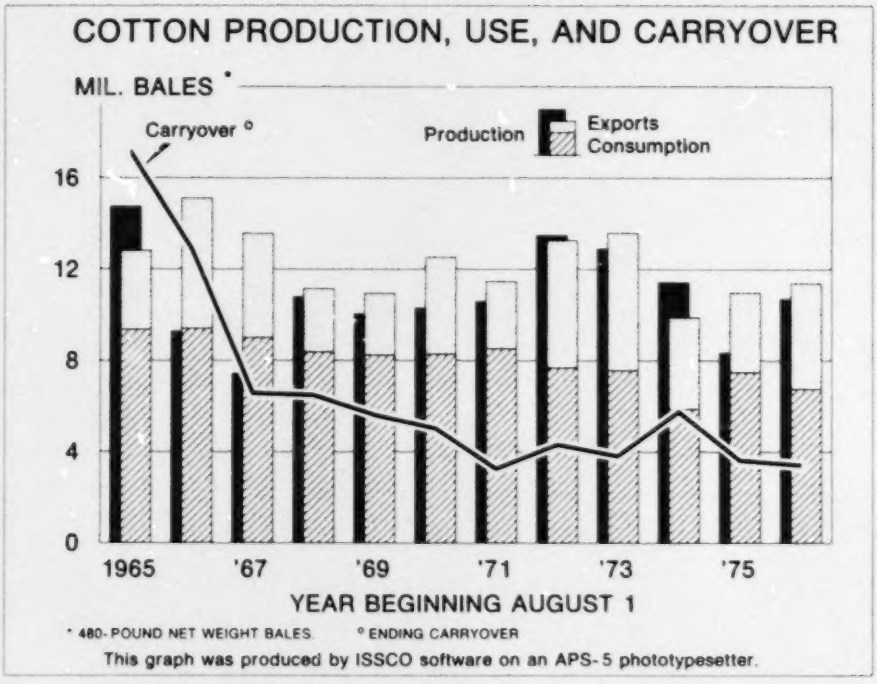

Figure 9. Computer generated copy

It should be noted that these are not exotic research results, but graphs made with commercially available products at very reasonable cost.

By the way, it may be legitimate to ask if this level of quality is really needed. Or is it overkill, snobbery, unnecessary and expensive finetuning? We think not. The importance of graphical quality cannot in our view be overestimated.

Many computer graphics practitioners tend to think in terms of cost/benefit behavior like this - the better the graph, the more valuable it is:

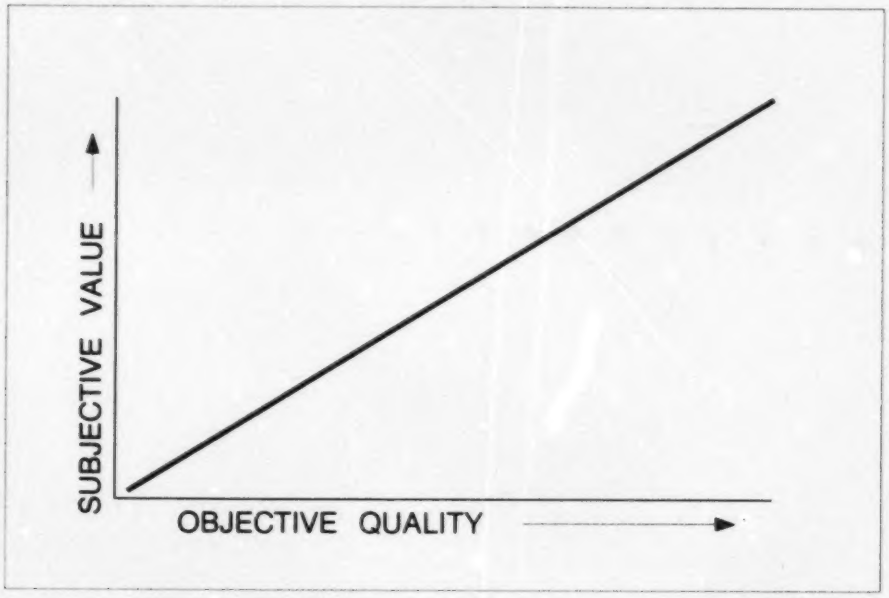

Figure 10. Simplistic cost/benefit behavior

or perhaps, given the laws of diminishing returns, like this - if the graph is very poor, small changes in quality don't matter, and if the graph is very good, we don't appreciate further improvement:

Figure 11. More realistic cost/benefit behavior

In our experience, among actual users of graphics a reaction like this is to be expected:

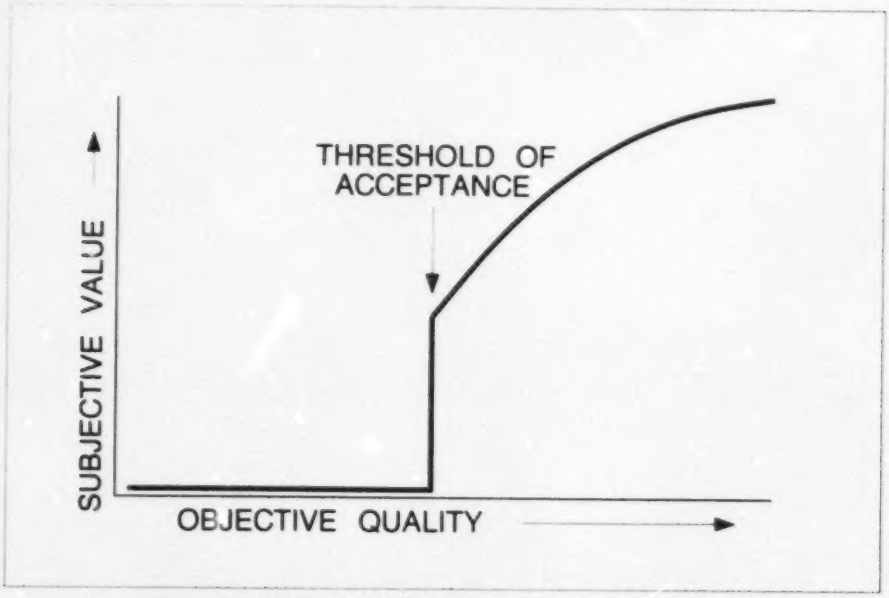

Figure 12. More realistic model of cost/benefit behavior

If a graph is not good enough for its intended use - if the quality level is below some threshold of acceptance - it will need to be redrawn by hand, and then its value to the user is near zero. Once the graph surpasses the quality threshold, it is appreciated according to the laws of diminishing returns.

Thus, if the graph is not good enough to be used, it matters little if the hardware and software are inexpensive, efficient, easy to use, reliable, portable, and all the other good things. The cost-benefit ratio gets pretty dismal when the benefit is zero, regardless of the cost.

The exact location of the threshold of acceptance varies with the application, of course - fortunately for the computer graphics industry. There were users eager enough for the economies of computer graphics to accept even the quality level of the late sixties. If there hadn't been, computer graphics would never have gotten off the ground.

But if we are ever to widen our horizons, if we are ever to achieve the maturity of dropping the word "computer", we must get past the high threshold of acceptance of the majority of graphics users.

HOW DO WE LEARN TASTE? AND TEACH IT?

But assuming that the technology is under control, how do we achieve the maturity, taste, and imagination needed to produce effective graphics? How do we educate the users? How do we help a manager, engineer, or clerk to produce an effective graph? Or, to be dramatic, how do we prevent a bad graph?

The first step is to recognize that graphics is not, like computer graphics, a new field. It is at least some 40,000 years old - as illustrated by the cave paintings of Altamira. This age and maturity can help us solve our problem.

There are people who know how to do good graphics. All we need to do is swallow our pride and listen to the graphics professionals, recognizing that we are walking into a field where we are the amateurs: the psychology and artistry of graphic representation. Computer graphics professionals must be trained in graphic representation.

(One problem with working in an old field is that we, like computer typesetting experts, are in the unfortunate (or fortunate?) position of being critized by amateurs. Any civilized human recognizes a good graph or a well typeset page of text when he sees one - and tells us loudly when he sees a bad one. We can but envy the makers of compilers and data base management systems their peaceful environment, and accept and learn from the criticism from the man on the street, our final customer.)

However, we have another ambition that poses an even harder problem. We want to make this tool available not only to graphics professionals, but to anybody with access to a computer - in this day of the micro, to everyman.

For a graphics professional, expertise is readily available. There are schools for graphics artists; there are books, teachers, and seminars. (Some useful books are listed in the bibliography) But if you are an expert of finance, engineering, or politics, you can't afford to learn all the rules of graphics, or to practice enough to make perfect. You don't want to become an expert in another field - you just want some good results from a tool.

We have studied many of the books, talked to many of the experts, and attended many of the seminars. We have found the rules very useful - but there are so many of them! Any attempt at formalizing taste and style seemingly must lead to a plethora of rules, sufficiently complex and qualified to completely baffle the layman. It seems impossible to design a subset of rules, within grasp of the amateur, leading to reasonably good graphs without total understanding.

However, trying to understand the reasons for the rules may help us remember. We have found that many of the strange effects governing the efficiency of graphic representation may be explained in terms of the functioning of the major piece of hardware processing the graph - the human brain. A brief introduction to some recent findings about the workings of the brain might help us avoid the pitfalls - the pitfalls that professional graphics artists avoid by virtue of their experience, maturity, and "taste."

The rest of this paper will analyze how a human percieves a graph. We will look briefly at the visual processing of the brain and what it can tell us about graph design, annotation, and adaptation to media. We will also look at the sometimes contradictory effects of previous experience on the part of the viewer.

We will not attempt to list hard and fast rules; we will not offer solutions. Gregory Bateson has pointed out [Bate] that a rule of thumb is not an absolute law, but rather a general rule to which the exceptions are interesting (for example, General Rule: mass is conserved; Interesting Exception: nuclear energy).

Perhaps a good subtitle for a treatise on good graphics would be, "Some general rules with lots of interesting exceptions."

THE WORKINGS OF THE BRAIN

The most basic description of the brain, suitable for people with computer backgrounds, might be a computer with two I/O channels:

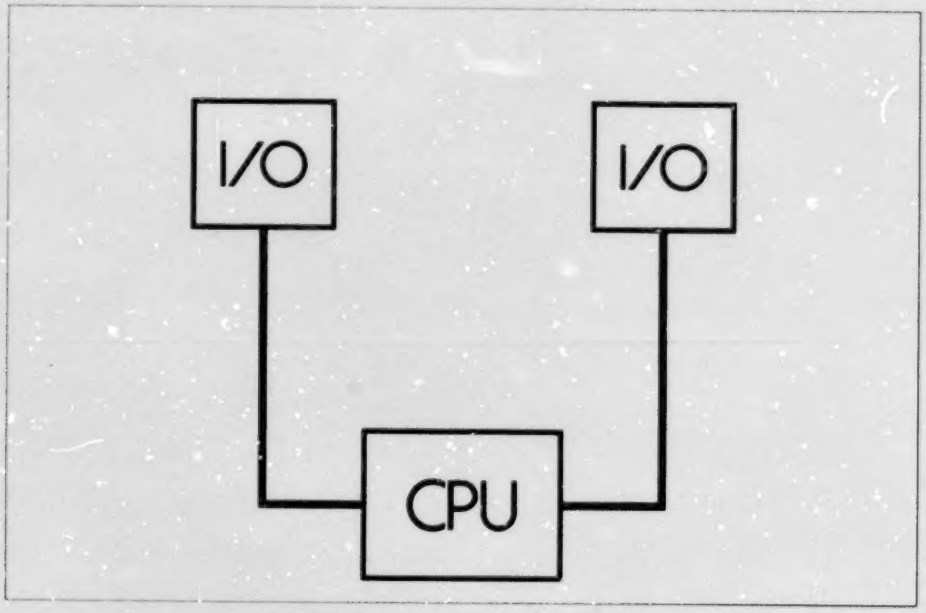

Figure 13. A simple brain model

However, even a casual glance at an anatomy book shows some very dramatic physical features of the brain, illustrated simplistically below.

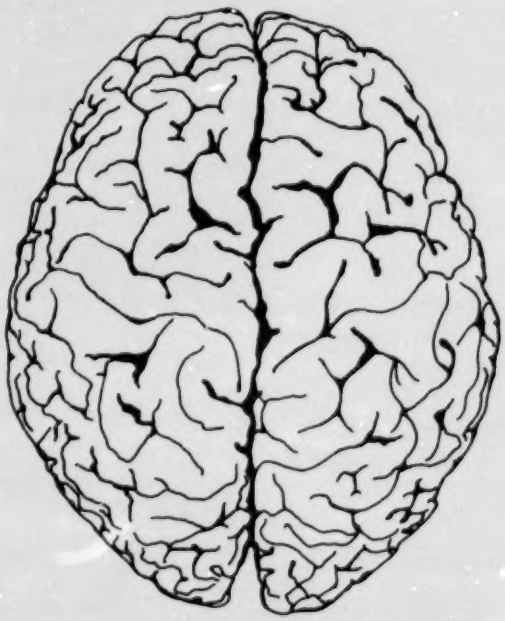

Figure 14. Overhead view of the brain (not computer generated)

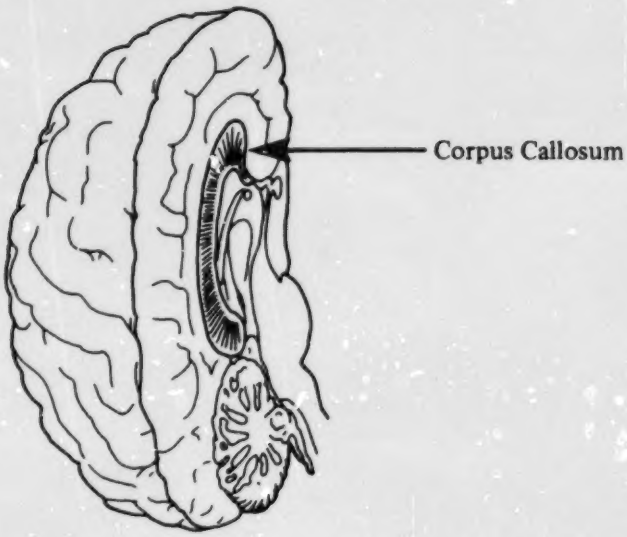

Figure 15. Cross section of the brain (not computer generated)

It is obvious that the brain is divided into two parts. Careful study shows no significant anatomical differences between the two parts. We also notice that the two parts are connected with a very thick nerve bundle, the corpus callosum. Further studies of nerve paths etc. suggest that a more realistic model might look like this:

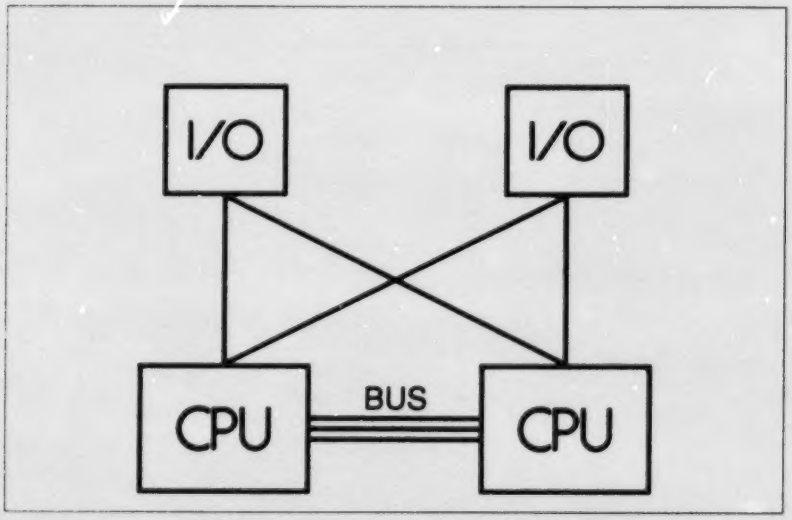

Figure 16. The left/right brain model

This is a very strange idea. Why are there two processors, apparently physically identical, and with access to pretty much the same information? Why is the brain duplicated?

Over the last decades, researchers have acquired a lot of insight into the workings of the brain. We will outline some of the current theories about the reasons for this duplicity.

It would appear reasonable that a very high bandwidth bus connecting the two CPU's would be a very important feature of the brain. However, some serious cases of epilepsy and other mental disorders are treated by means of severing the corpus callosum, and to the great consternation of everybody, there are no dramatic effects when this is done. The brain works pretty much the same even when the

two processors can't communicate with each other. Could the brain have a major physiological feature that doesn't do anything? This doesn't seem likely.

More careful studies revealed that there was indeed some impact from the severing of the bus. This was demonstrated by the fact that the eyes (and other things like motor control) are not connected completely to both halves of the brain. The left field of vision (not the left eye) is connected to the right brain, and vice versa. Experiments could be arranged that fed some information to only one half of the brain using split fields of vision, feeling objects with only one hand, or something analogous. It was found that the brain halves have a lot of specialization of function.

The most well-known effect is that the left half of the brain is responsible for talking. Showing a split-brain patient an apple in the right field of vision, feeding into the left half of the brain, allows the patient to state, "It is an apple." However, if an orange is now shown in the left field of vision, feeding the right half of the brain, the patient is stuck with a communication problem. The right brain knows it sees an orange, but is not in charge of speech. The left brain, which doesn't know exactly what is going on in the left field of vision, does the best it can and states, "It is an apple." The right brain, hearing this (hearing, incidentally, is controlled by the right brain), knows it is nonsense. Not being capable of speech, the right brain in frustration communicates as best it can - it shakes its head The patient says "It is an apple", shakes his head, and then in bewilderment asks, "Why am I shaking my head?"

Many incidents like this are reported in the literature, some of them including quite hilarious effects (like patients "cheating" by communicating between the brain halves with a softly whispered, "Apple"). The story of this research, which is still ongoing, is quite interesting in itself.
However, we will skip ahead and look at some of the results.

LEFT	RIGHT
LOGICAL	INTUITIVE
ANALYTICAL	HOLISTIC
NUMERICAL	SPATIAL
TEMPORAL	NONTEMPORAL
VERBAL	NONVERBAL
SYMBOLIC	CONCRETE

Figure 17. Some keywords for left and right brain function

In general, the left brain is in charge of logical, verbal, symbolic, numerical, temporal processing of the data; while the right brain is in charge of visual, holistic, intuitive processing. The brain performs the quite advanced trick of feeding the same information to two processors specialized for two different types of analysis, and then letting each one come up with whatever results it can. (Incidentally, since there is virtually no physiological difference between the two halves of the brain, it appears the specialization is mainly in software.) The results are normally communicated between the two processors through the corpus callosum.

In most people of the western culture, the type of processing done by the left brain dominates. We can see that the keywords associated with the left brain have a very positive flavor, while the right brain words appear somewhat dubious (perhaps a conspiracy by left brains, which control words...).

Aside from the appreciation of looking at a rose, a sunset, or a Picasso, the main example of results from the right brain is the "flash of intuition." Faced with a difficult problem, the left brain carefully and methodically plods along working all the details out - but sometimes the right brain leaps in with a solution which seems to come out of thin air. The concept of two independent, asynchronous

processors treating the same data fits very well with some classical writing on the nature of intuitive and inventive thought. The right brain is best at looking at a whole situation, getting an overview feel for what is going on, and supplying a ready answer. The left brain is best at analyzing details, calculating effects, and giving numbers. The total brain, drawing at both of these resources, is capable of producing a computer program and a poem on the same day - or looking at a graph and a table in the same report.

One might well ask, is this just high-falutin' theory, or can we really use these ideas for practical results? One example of practical results is the work done by Betty Edwards [Edwa]. Ms. Edwards is a teacher of artistic drawing. She was irritated by the fact that most adults draw on the same level as a typical 10 year old, and that there is really no way to teach better drawing. Drawing is taught by showing good examples, and practice. But by basing her teaching on the theory of left/right brain function, Ms. Edwards was able to achieve some pretty stunning results, as illustrated below (compare the dates, before and after the course).

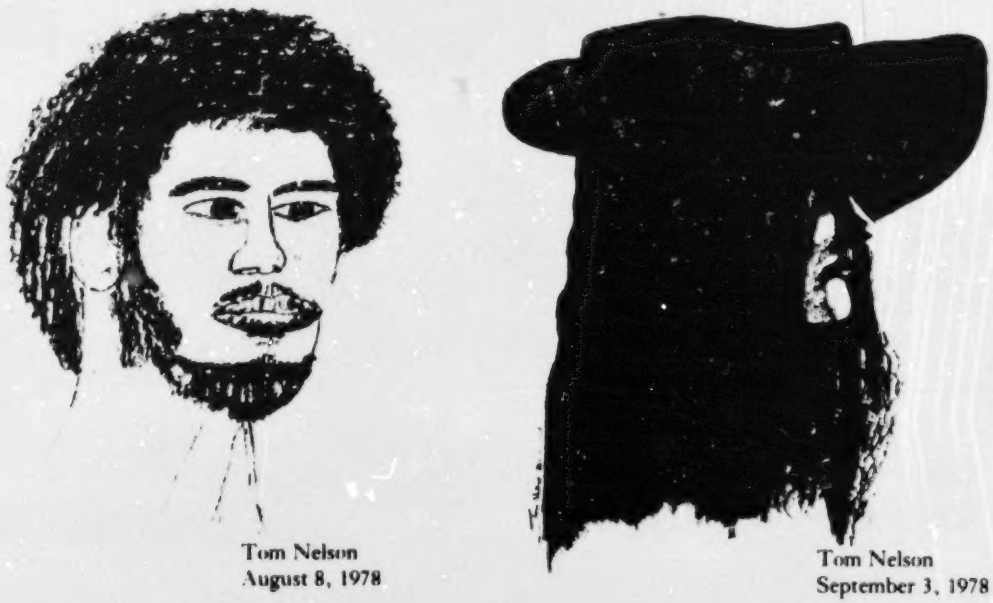

Figure 18. Drawing skills before and after right brain teaching (Reproduced from [Edwa] by permission)

Ms. Edwards recognizes that many of the bad things drawn are symbols rather than pictures. Rather than letting the right brain, the visual one, draw the shape of a pair of glasses, the dominant left brain jumps in saying, "I know what these are; they are a pair of glasses; here is my symbol for glasses, two circles and some hooked lines." By means of some pretty radical exercises, Ms. Edwards forces the left brain to withdraw and leave the task of drawing to the processor best suited for the task, the right brain.

GRAPHICS FOR THE RIGHT BRAIN

We might be able to achieve some similar results by recognizing that when we look at a graph, it is the right brain that does the processing of the visual and graphical information. We must design our graphs so they are suitable for right brain analysis. We can not solve visual (right brain) problems by means of talk, text, explanations, or numbers (left brain information).

Optical illusions

The right brain picks up the graphical impression without having any understanding of the meanings of the numbers. Optical illusions and other strange visual effects may create an impression opposite to that intended. The left brain eventually gets in to analyze the numbers, but the initial impression of the right brain may badly muddy the waters.

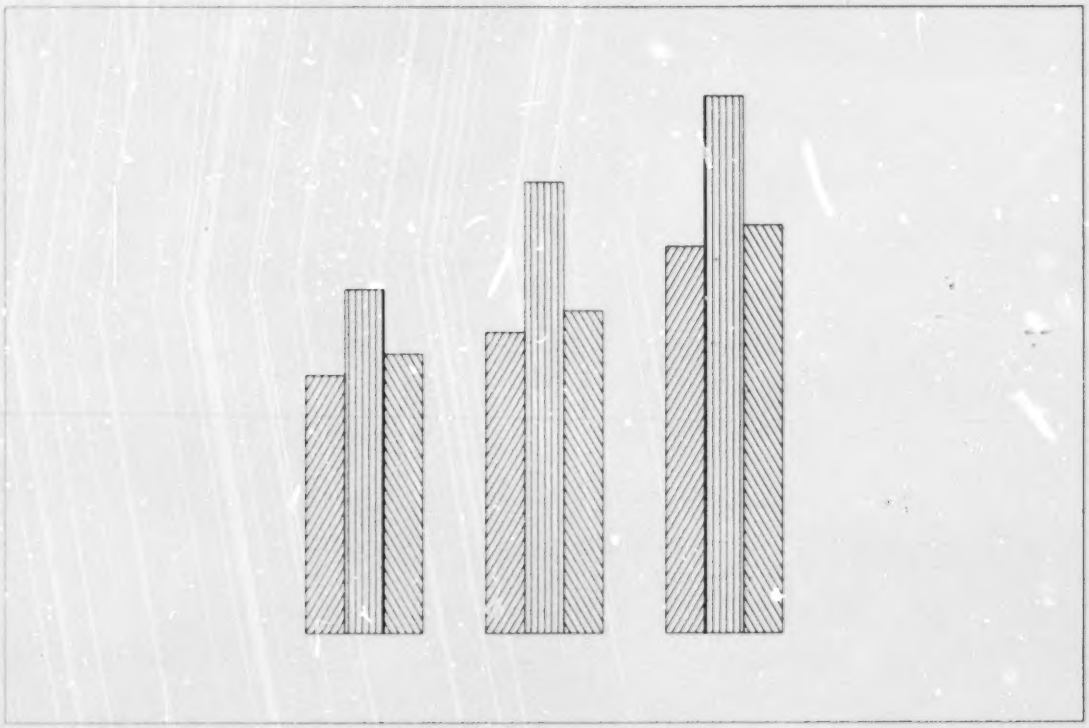

Figure 19. Leaning bars effect created by optical illusion

We are all familiar with the simple optical illusions like the one illustrated above. This one is easily avoided by careful selection of shading patterns. However, there are many other subtle effects lurking among all the graphical flavors produced by our very sharp tool.

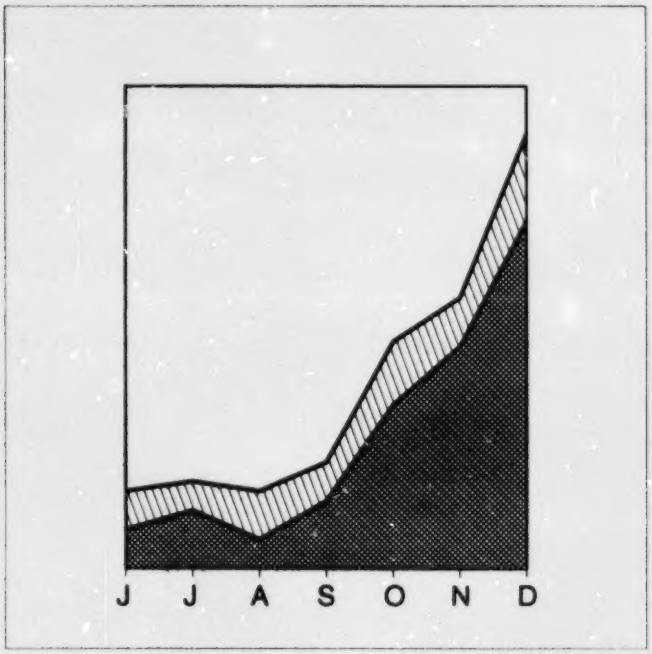

Figure 20. Misleading graph because of optical illusion

For example, the graph above gives the definite impression that profit was highest in August - except that the bar chart below shows that profit was much higher in December. Looking at the area plot above, we get fooled because the right brain sees the "profit" area as a thin band, and latches on to the *width* of the band rather than the *vertical height*. The width is determined by the angle of the band as well as the actual height. The bar chart is a safer graph in situations like these.

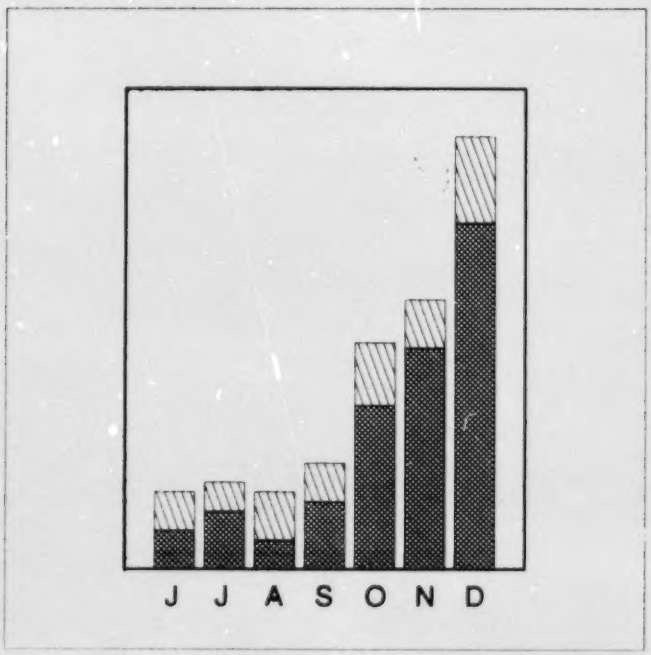

Figure 21. Bar chart shows the real data

If for some reason we want to use the area plot rather than the bar chart, we must make sure that we do not have thin bands at a slant. A reorganization of the plot so that profit makes a horizontal thin band along the bottom gives the right impression.

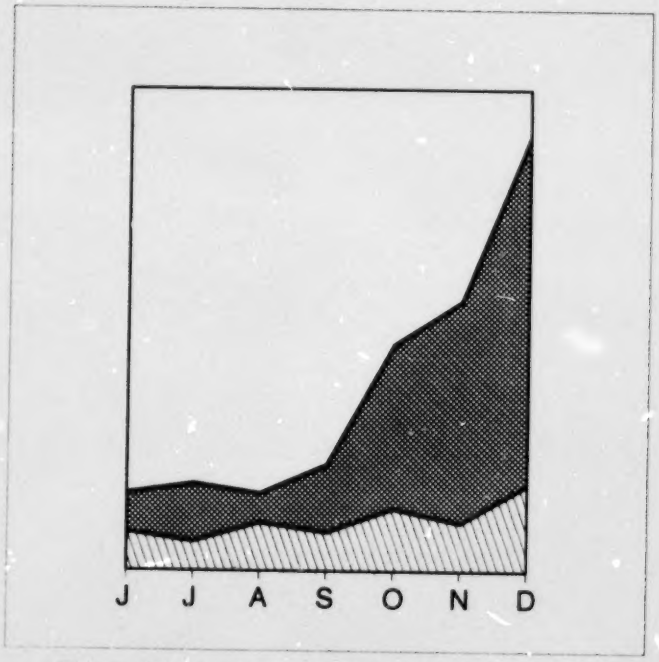

Figure 22. A better arrangement of the area plot

An even simpler effect, easily avoided, is the apparent jaggedness of the area labeled "AUTOMOTIVE" below. The "HARDWARE" area, which is really very uneven, causes all the other areas stacked on top of it to appear uneven as well. The "AUTOMOTIVE" sales volume is really very nicely constant. A simple rearrangement solves this problem:

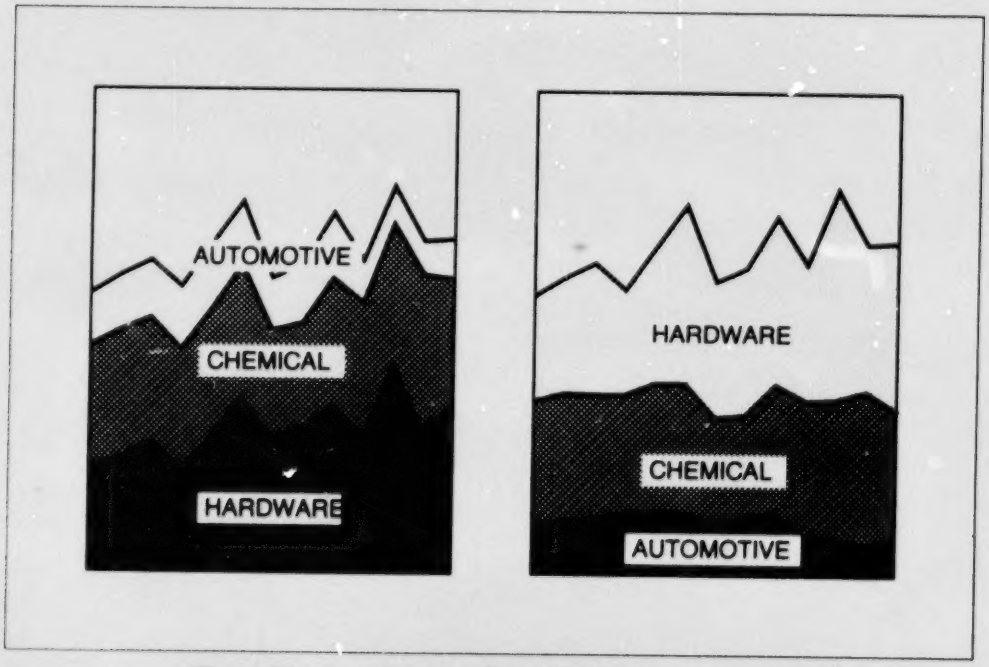

Figure 23. A misleading effect solved by rearrangement

Of course, effects like these may be abused to great effect. Gene Zelazny [Zela] has pointed out that if we want to hide the bad news illustrated below - administrative costs rising astronomically - all we need to do is rearrange the graph so the "ADMIN" band rides on top of the peaky "OTHER" area. The modified graph actually gives the impression of decreasing administrative costs, and will certainly make the stockholders feel much better.

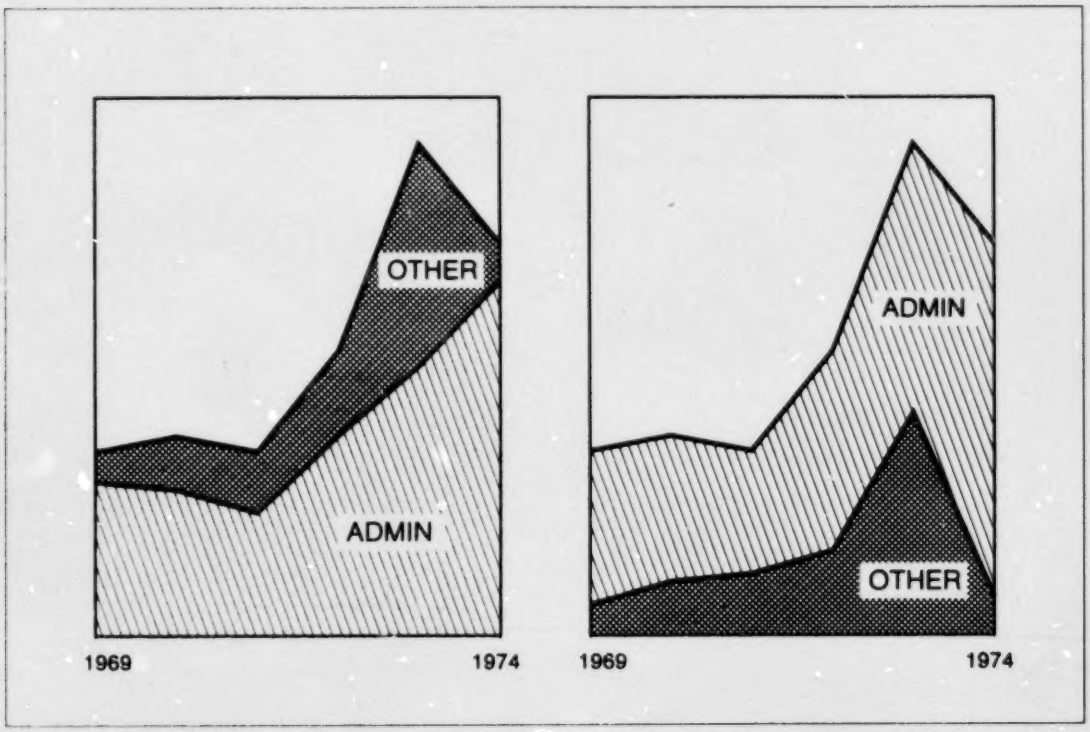

Figure 24. Uncomfortable data may easily be masked

This discussion generally assumes we are trying to be honest. To actively mislead, do exactly the opposite of the advice herein.

Graphs are not tables

Careful labeling of a graph may seem useful, but the visual processing of the right brain may get confused by the graphical impression generated by the blackness of the text.

For example, assume we want to show this information:

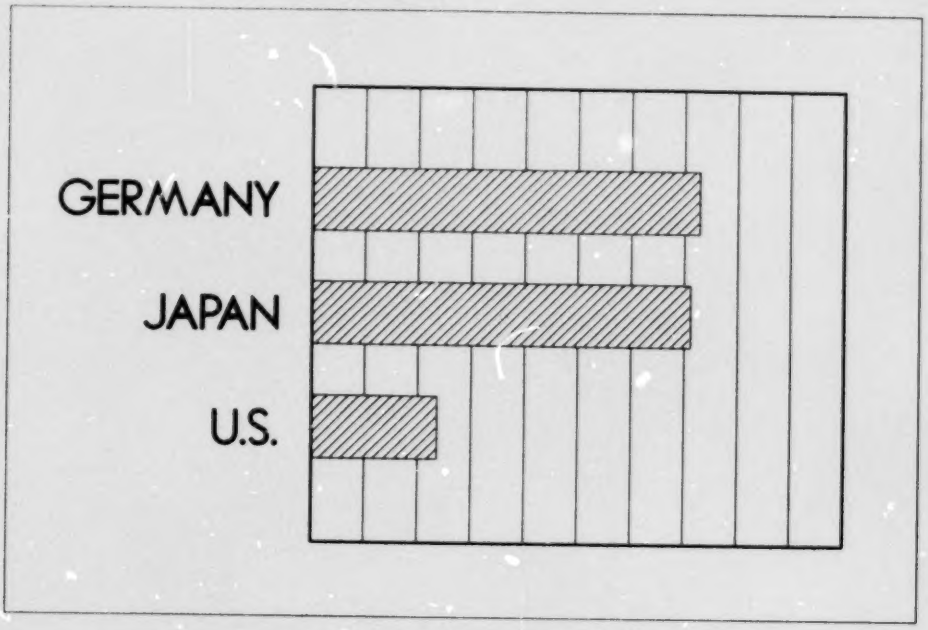

Figure 25. We mean this

Overzealous labeling produces this:

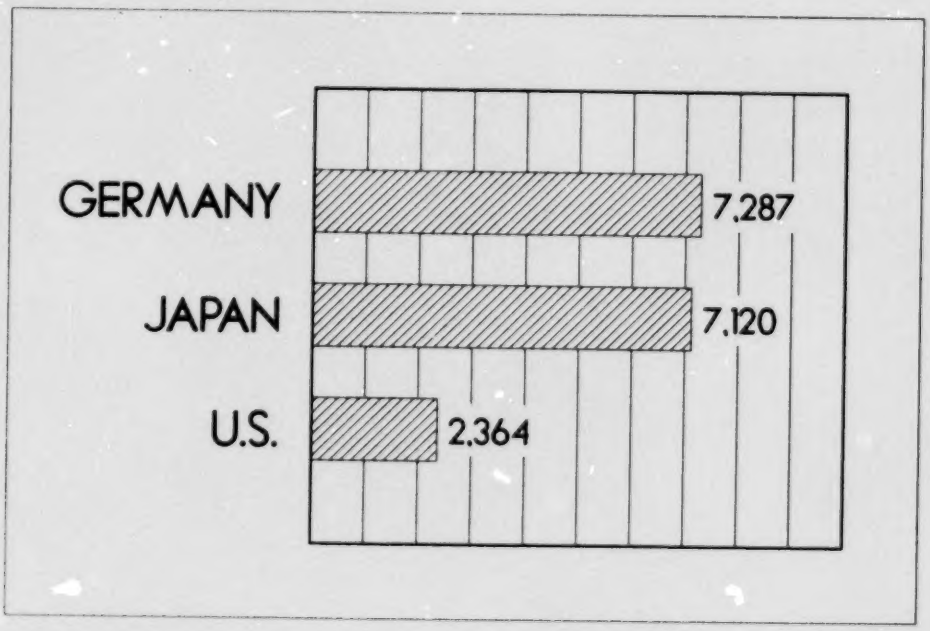

Figure 26. We draw this

The right brain might under some circumstances be fooled into visually integrating the numbers into the shape of the bars, in effect "seeing" this:

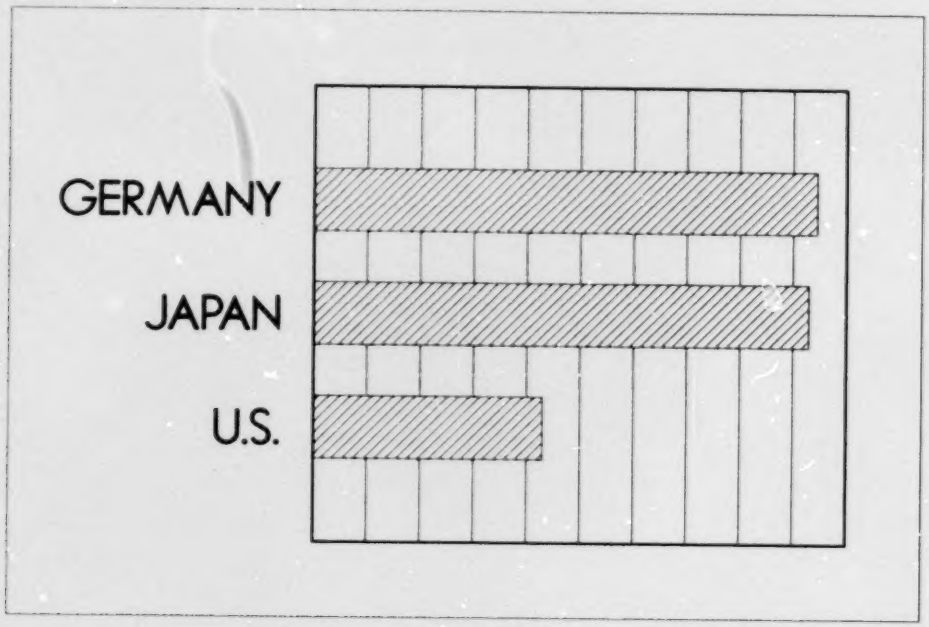

Figure 27. The right brain sees this

It is obvious that the proportions of the three bars changed dramatically, even though the rankings are the same. The visual impression of the graph differs completely from that intended, and from that shown by the numbers. The right brain is in conflict with the left brain.

Conversely, intending to show data which really look like this,

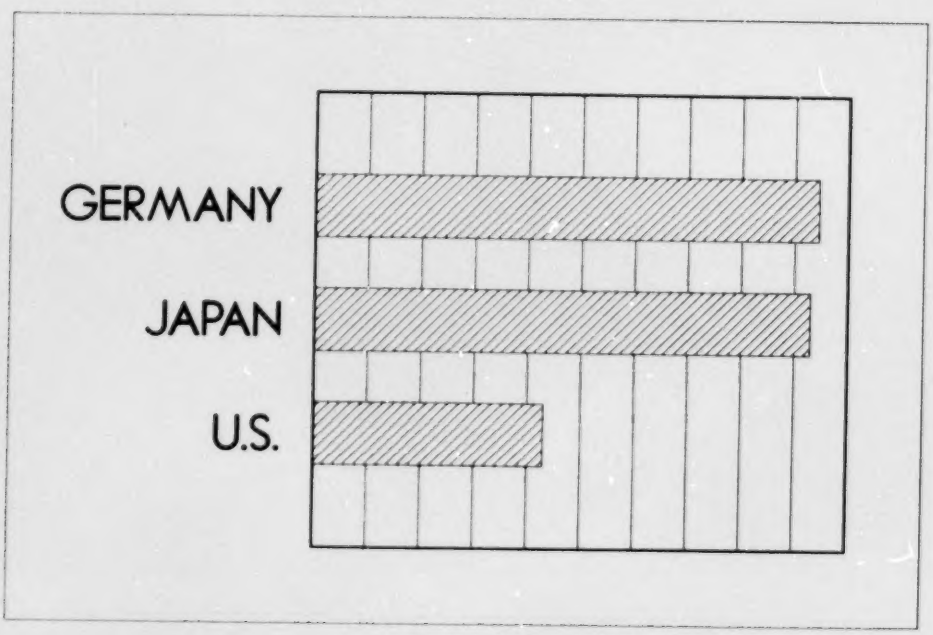

Figure 28. We mean this

we might decide to make a graph like this:

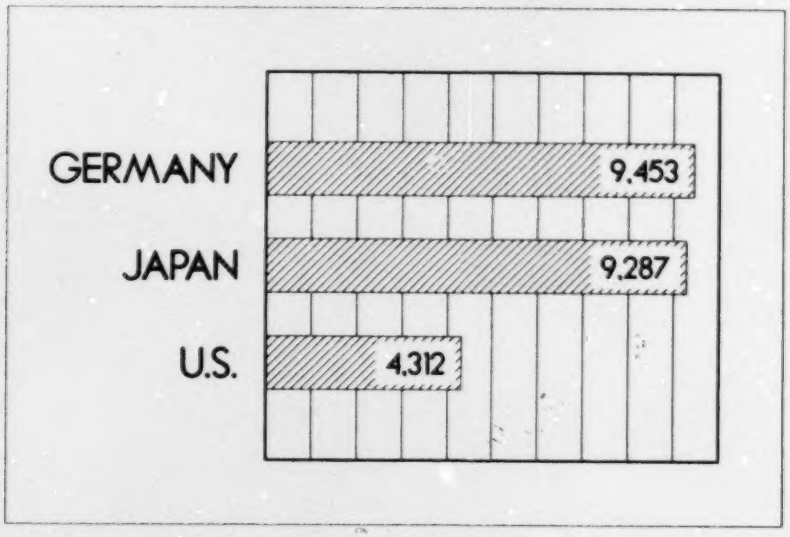

Figure 29. We draw this

The right brain, seeing the big holes in the shading of the bars, might visually delete that area from the length of the bar and "see" this:

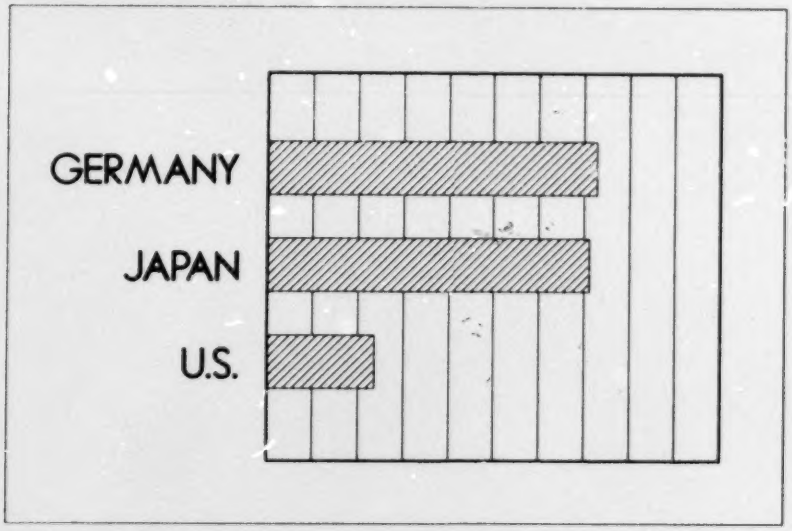

Figure 30. The right brain sees this

Again, the proportions changed dramatically.

These two effects are obviously contradictory - in one case the annotation adds to the bar, in the other it detracts. Which one is right? There is no easy answer. Which effect predominates may depend on shade pattern, color, typefont, lettering size, etc. We are getting into deep water. The success of the graph has come to depend in a fairly unpredictable fashion on many minor details, some of which may be beyond our control. This kind of sloppiness cannot be allowed. If we must annotate the graph, this might be a better solution:

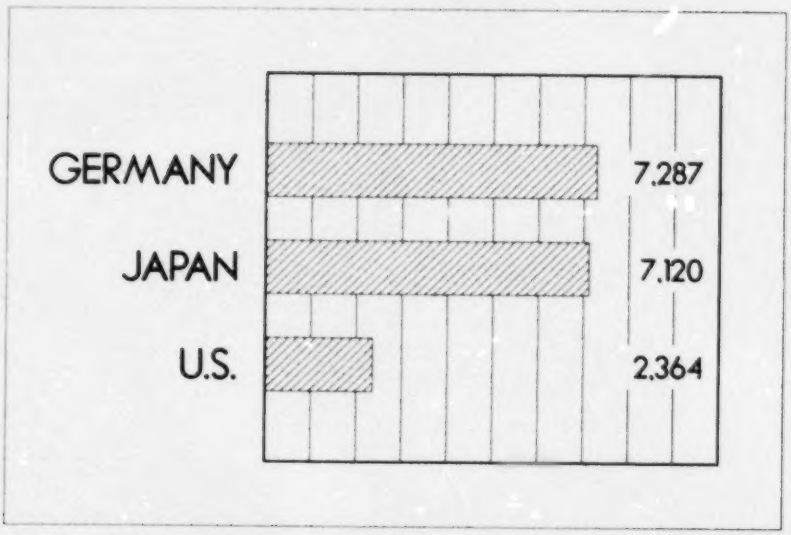

Figure 31. A better solution?

Better still, avoid numbers on graphs altogether. Graphics is information aimed at the right brain. It should be used to convey trends, overviews, general behavior. If you want to report values to the nearest cent, use a table. A graph and a table work well together - perhaps even merged as in the example above. But remember, *don't make a graph do the work of a table.*

Use grids sparingly

For the same reason, grid lines should be used sparingly, if at all. A grid should be used to give the eye (the right brain) a clue, not for reading the data. This graph:

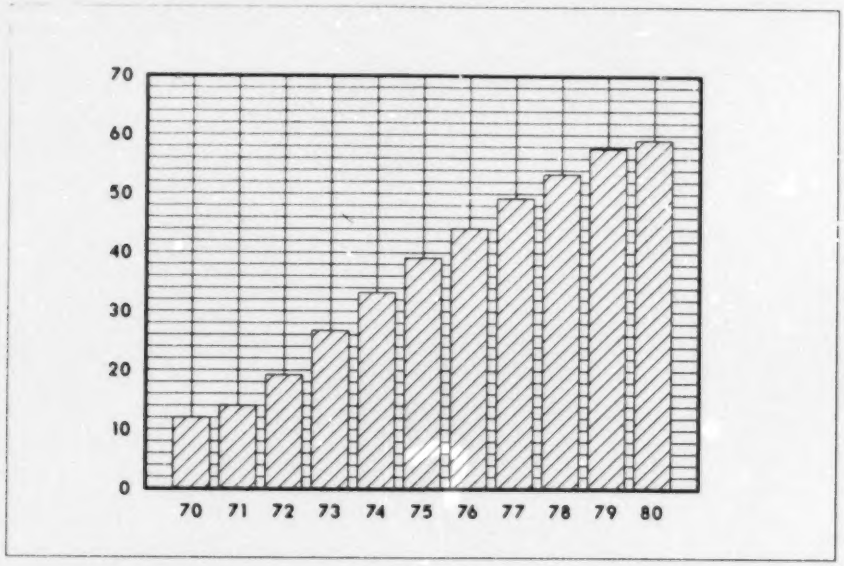

Figure 32. Overgridded graph

is considerably less effective than this:

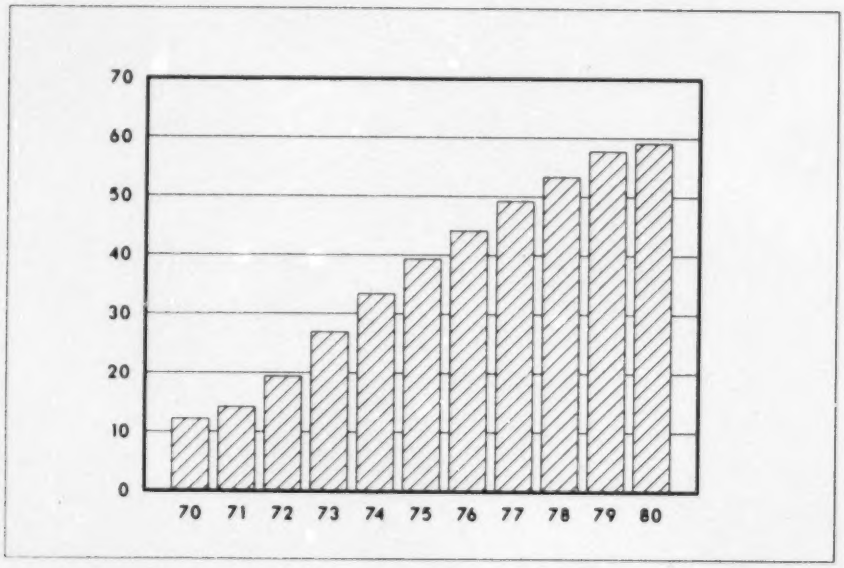

Figure 33. More sensible amount of gridding

We already have the numbers in the computer - if we want numbers, why not print them? Plotting them and then laboriously reading them off the graph with the help of a grid is a ridiculous waste of time. **Visual emphasis**

The unnecessary grids distract the visual perception of the right brain. Similar problems can occur when line weights are not chosen right. Since most computer graphics hardware does not allow line weight control, it is not uncommon to see graphs like this:

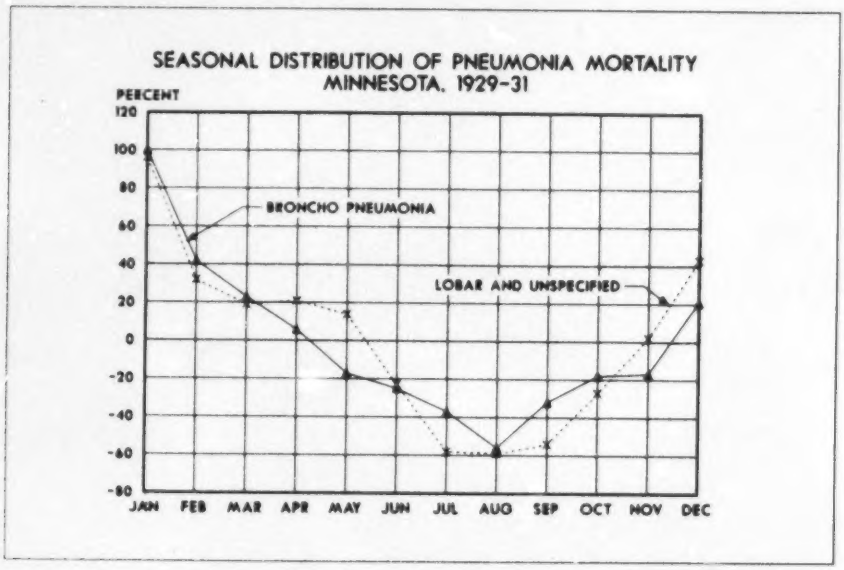

Figure 34. Poorly chosen line weights emphasize grid and frame

The technological problems of controlling line weight have been solved, however, and the data can now be given proper billing, ahead of frames, grids, annotation, and other decoration:

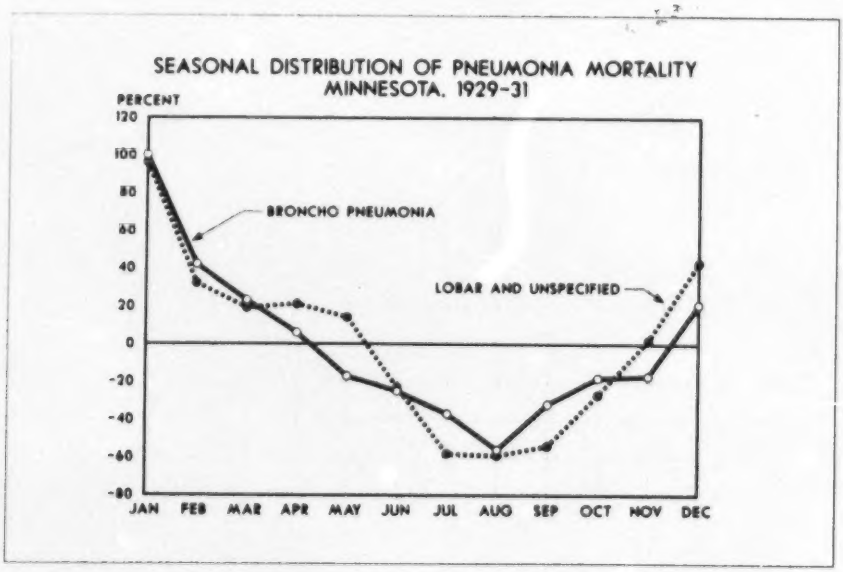

Figure 35. Emphasis should be on data

This detail is considered to be of major importance by graphics artists. Poorly chosen line weights is often the major reason computer generated graphs are rejected, much to the surprise of the computer graphics experts.

Be flexible about layout

Computer graphics systems usually provide standard layouts, but the visual impact may often be significantly enhanced by minor layout changes. When retrieving information from a data base we often get it in some specific order, for example alphabetic:

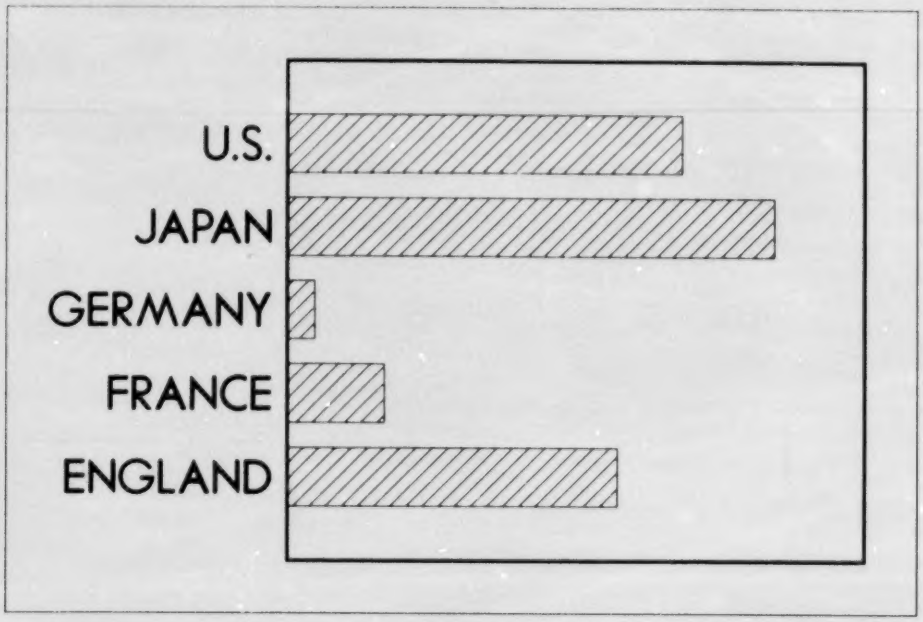

Figure 36. Alphabetically arranged graph lacks immediate impact

To find the ranking of the U.S. among the five countries, we must compare all the values (left brain work!). By simply sorting the data, we immediately show what the rankings are.

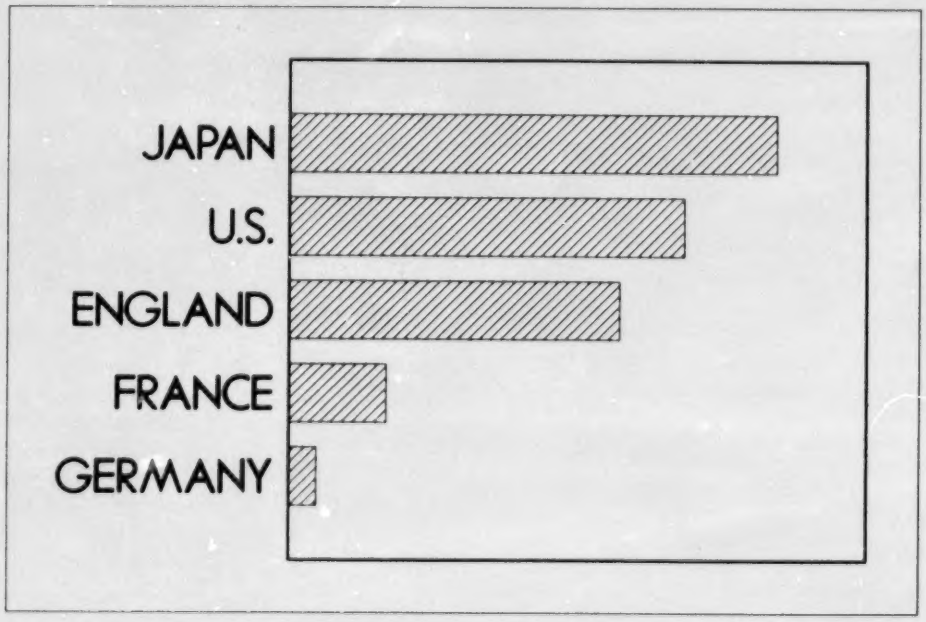

Figure 37. Sorting by magnitude aids comprehension and retention

Sometimes we gain by going even further away from the classical layouts. Here the ascending nature of the data suggests placing the vertical scale on the right of the graph:

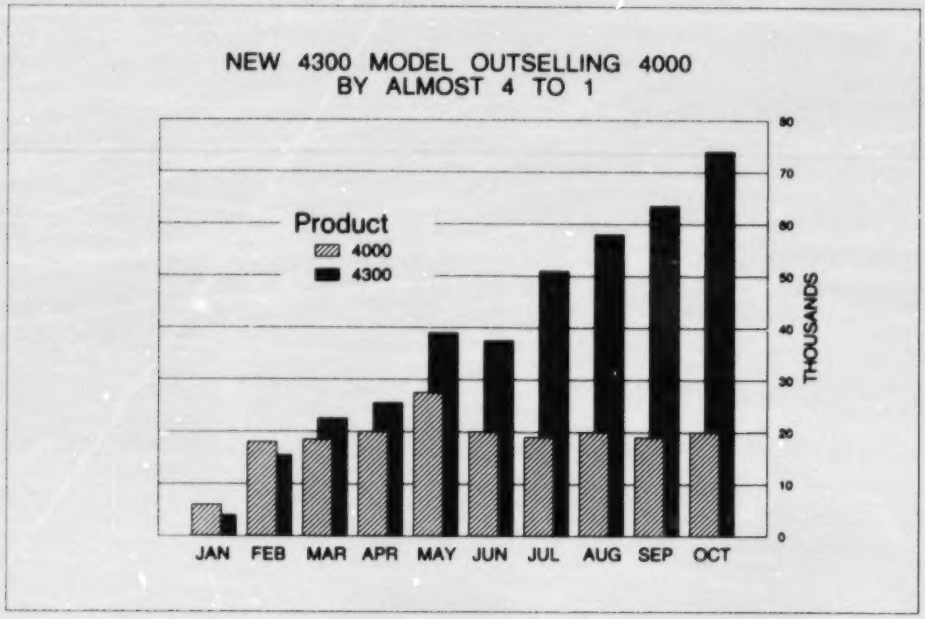

Figure 38. Unorthodox layout aids in reading graph, and gives more pleasing appearance

In the next case, we note that the lengths of the labels happen to match the data. We can rearrange this graph altogether so that the labeling takes less of the precious space:

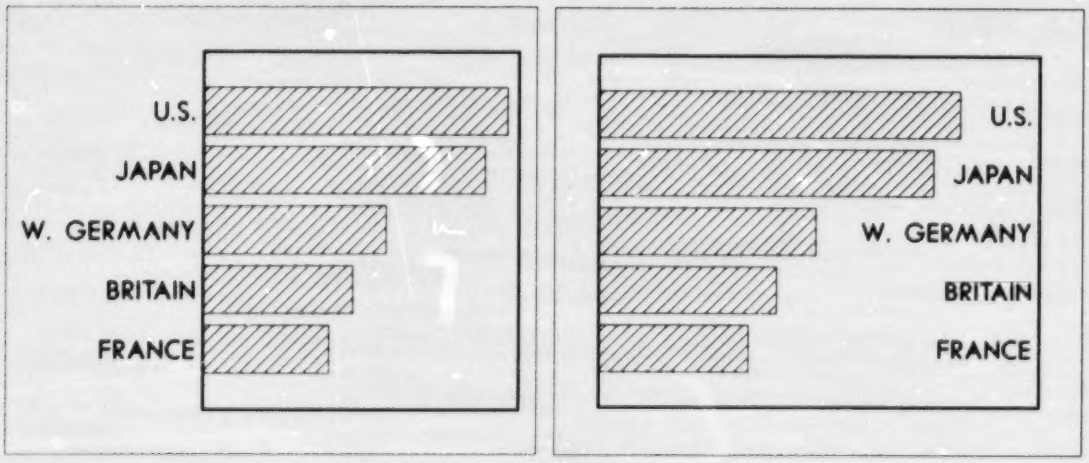

Figure 39. Rearrangement saves space, gives more room for actual data

However, this kind of flexibility can be taken too far. Within the context of one report or presentation, widely varying layouts tend to confuse the audience. If data in several graphs is comparable, the layouts and the scaling should be similar. Otherwise the right brain cannot compare visually, and the left brain must transform the information into numbers and compare numerically - the graphs failed.

Indeed, similarity of layout actually implies similarity of content - to the extent that a change in layout is an effective way to emphasize dissimilarity.

(In other words, we have a General Rule: You Should Be Flexible About Layout, and an Interesting Exception: Except When You Shouldn't.)

THE CONFLICTING INFLUENCE OF EXPERIENCE

We are not dealing with unschooled right brains, however. We have all been inundated with graphics since early childhood, and we must recognize that some conventions should be adhered to whether we can see a reason for them or not. An otherwise good graph showing profit in red is not going to be a total success, nor is one showing loss upwards and profit downwards:

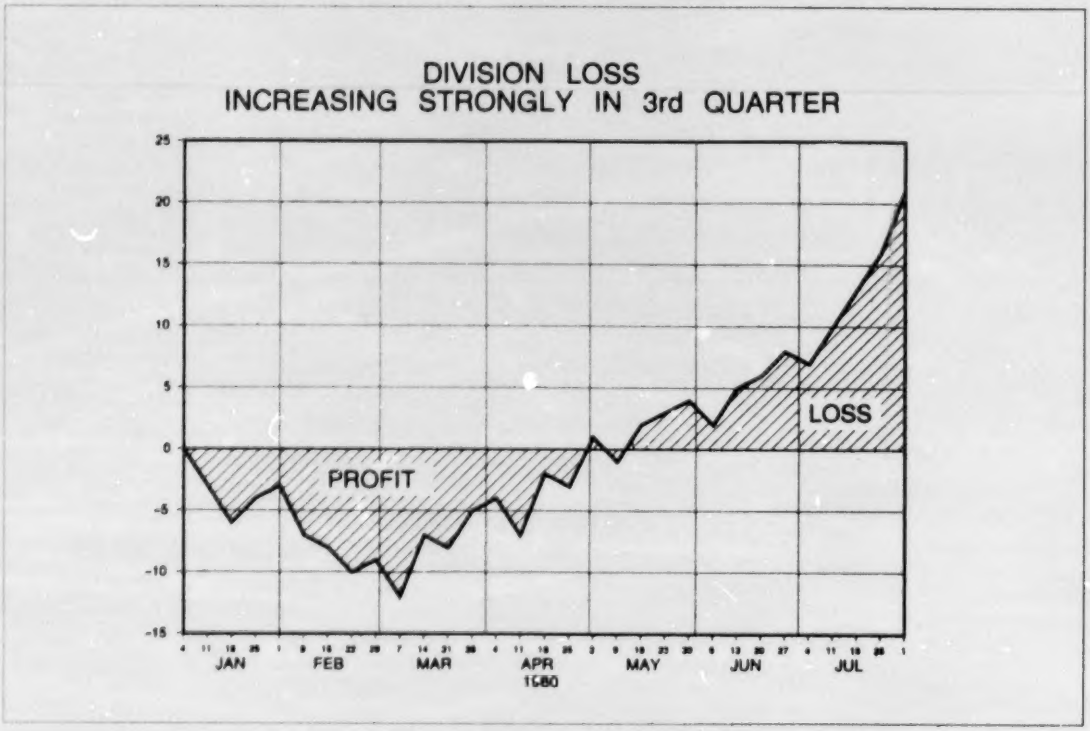

Figure 40. Unconventional arrangements may decrease comprehension

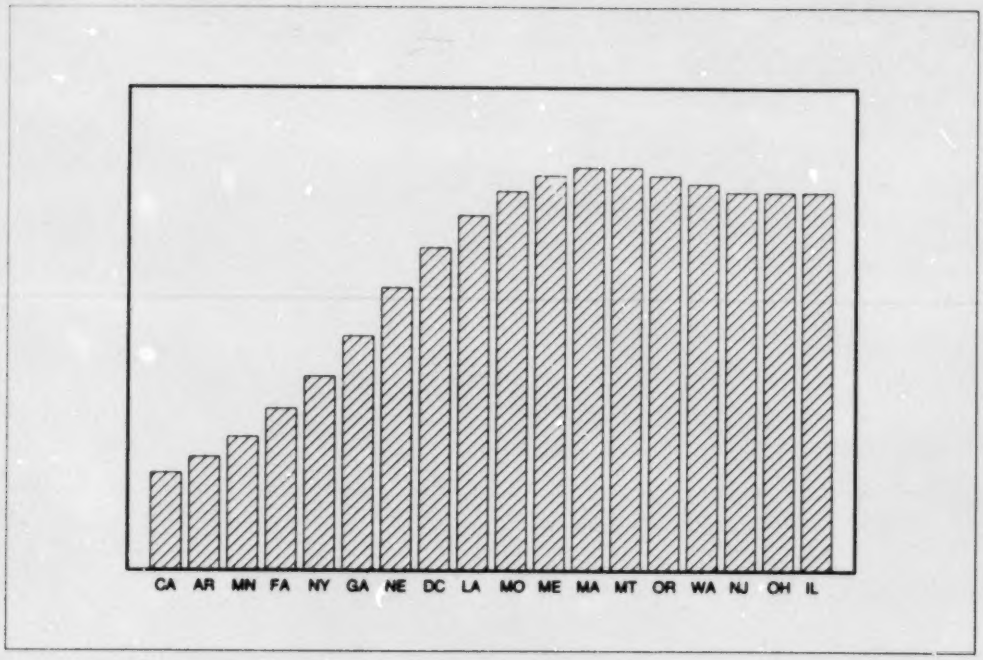

Figure 41. Categorical variable along X axis...

A less obvious convention is that the X axis is often time. Therefore, if the independent variable is not time, it is usually safer to place it along the Y axis. Looking at the graph above, is is hard to resist thinking in terms of something increasing, leveling off, and then decreasing slightly. But we did not have a time series chart; the independent variable did not flow year by year, as it does here:

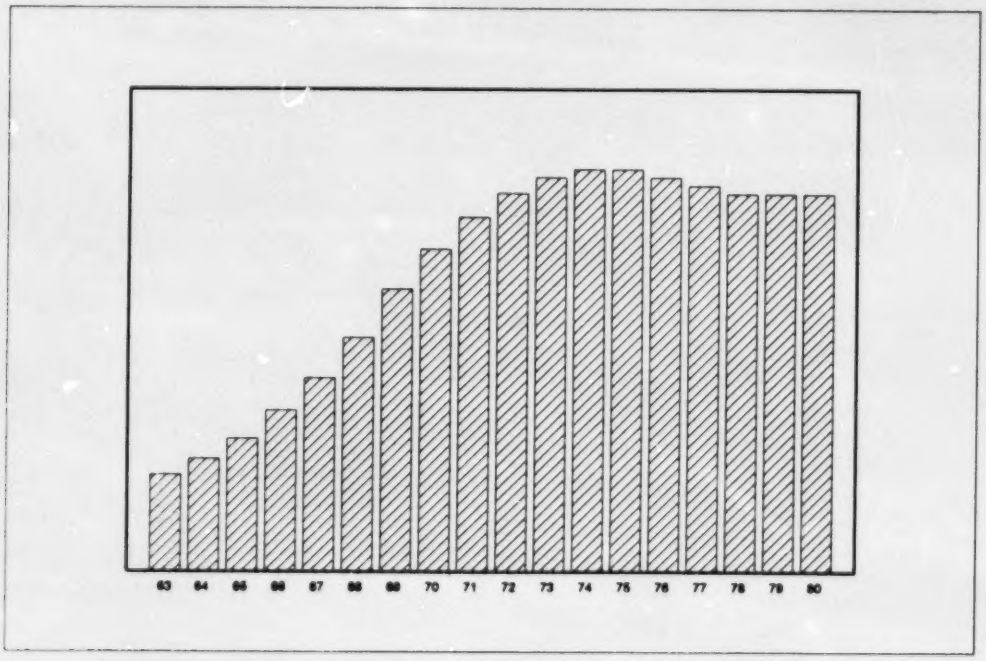

Figure 42. ...gives the appearance of time flow

Categcrical data like this is much better shown as a horizontal bar chart:

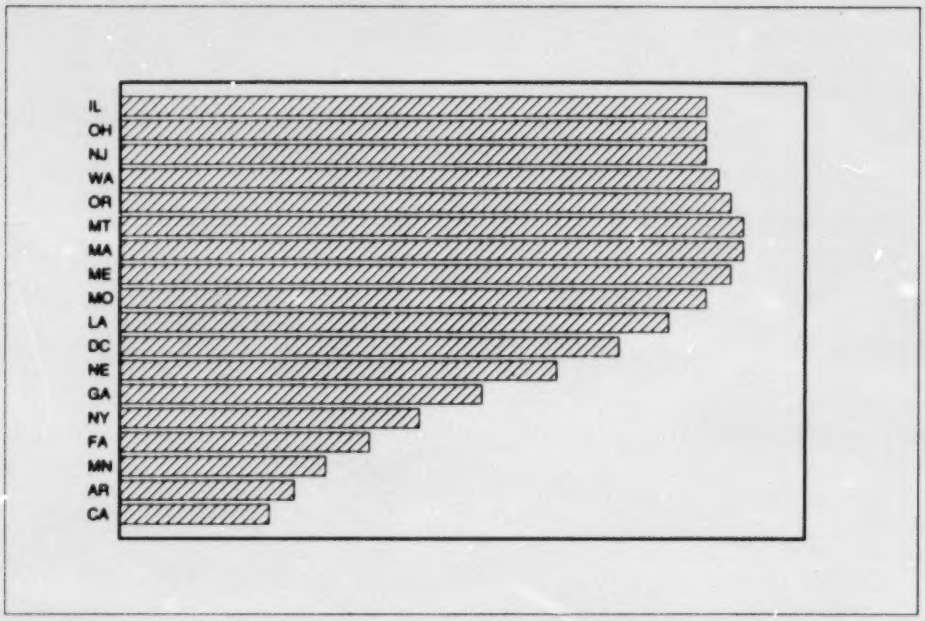

Figure 43. Graph with categorical variable along Y axis is less likely to be misunderstood

These conventions are not all problematic, however. They sometimes allow us to get away with simplifications that would otherwise be unclear. In this graph, originally published on the front page of a daily newspaper, the artist obviously felt that the average reader is sufficiently accustomed to the idea of inflation compensation to understand the graph even without a label identifying the values without compensation for inflation.

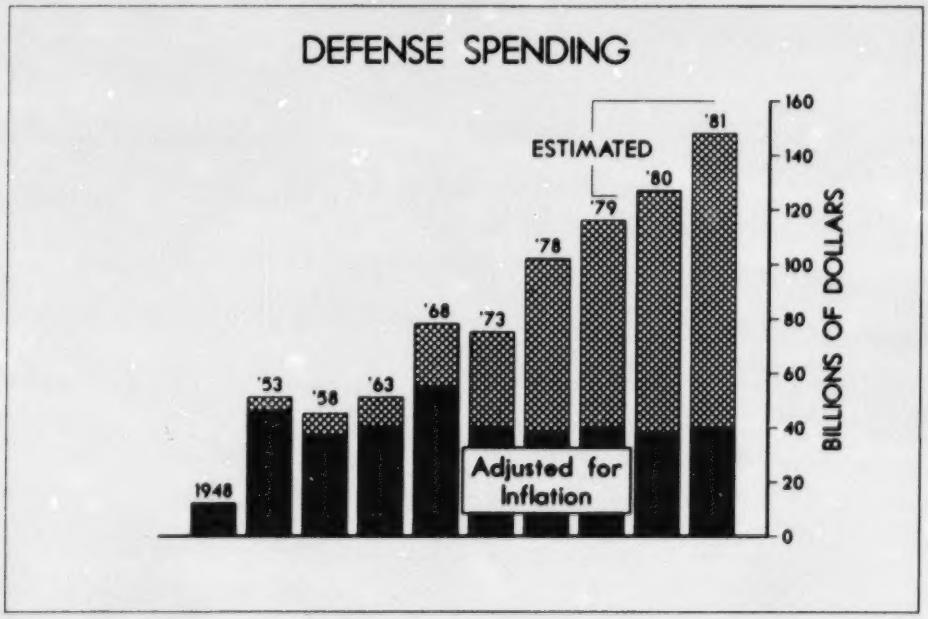

Figure 44. Underannotated graph is comprehensible to experienced viewers

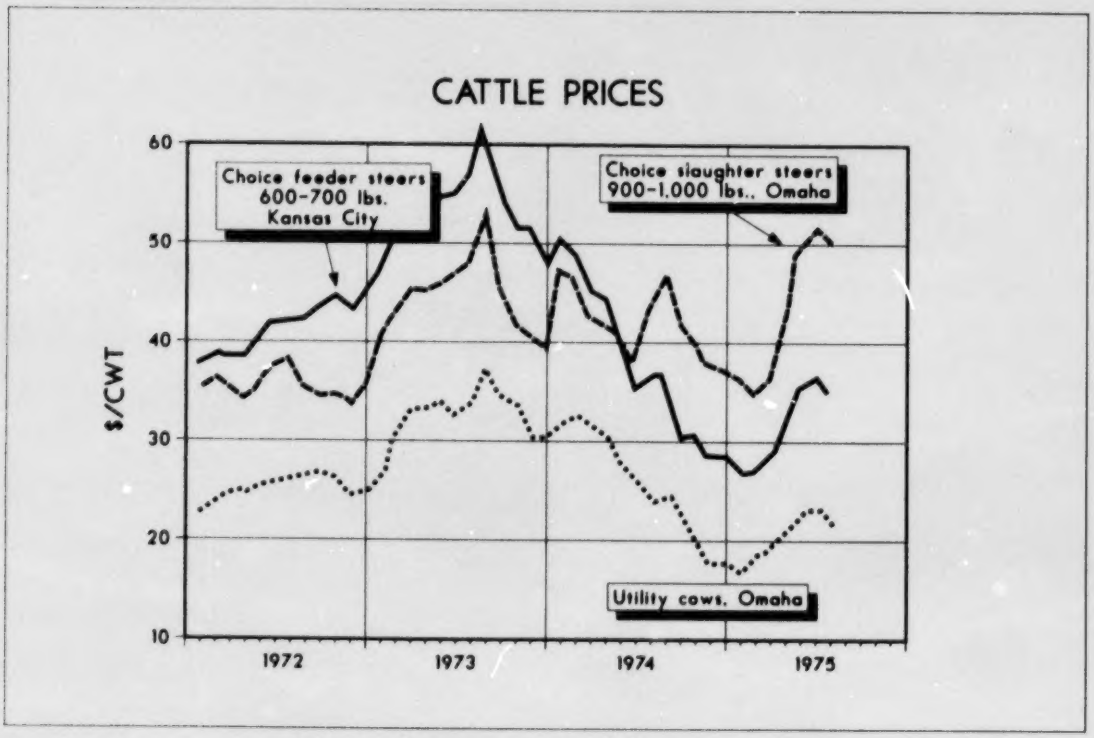

Figure 45. Dropshadows may lend visual emphasis and clarity to specific figure elements

We can also use some special effects to aid in visual perception, aiming at both right brain processing and graphical experience. However, when we get into this area, some restraint is needed. The last year there seems to have been some competition among the artists of the weekly news and business magazines. The resulting frenzy for variation, with fake three-dimensional effects, shadows, and other ornamentation, quite often make the graphs very difficult to read.

While the effects may sometimes be valuable, unwarranted prettification is not elegance. We would do well to remember another statement adapted from [Sieg]:

A definition of elegance:
Of two graphs of equal simplicity, the one conveying the most information is the most elegant.

Or equivalently:
Of two graphs conveying the same amount of information, the simpler is the most elegant.

William of Ockham (1280 - 1349) coined the immortal "Occam's Razor":

We prefer the simplest explanation consistent with the facts

It is perhaps doubtful that "Vinberg's Razor" will be quoted seven hundred years from now, but it might be a useful paraphrase today:

We prefer the simplest graph that gets the message across

ADAPT THE GRAPH TO THE MEDIUM

Among the technical problems we have to contend with in computer graphics are the peculiar idiosynchrasies of the various kinds of hardware. Low resolution devices require special typefonts and do not do justice to smooth curves. Some color combinations have high contrast on color CRT's but do not show up well on color microfilm. On some equipment white bleeds more than red. On microfilm colors blend and produce new colors; on raster devices the last color drawn predominates; on pen plotters, color mixing produces a smeary mess.

But these problems can be mastered. There are more important considerations in adapting to a medium. The same device may be used to produce originals for printed reports, slides, overheads, or technical memoranda. The medium is not the device producing the graph, but the eventual method of showing it. We must recognize that the same graph cannot be used effectively as as slide and a report illustration.

The slide version below must be comprehended very quickly and thus has minimal annotation; it is aimed squarely at the right brain. On the other hand comprehension is aided by the verbal message of the speaker giving the presentation. Color helps visual communication, and heavy lines and bold type fonts follow the stark style.

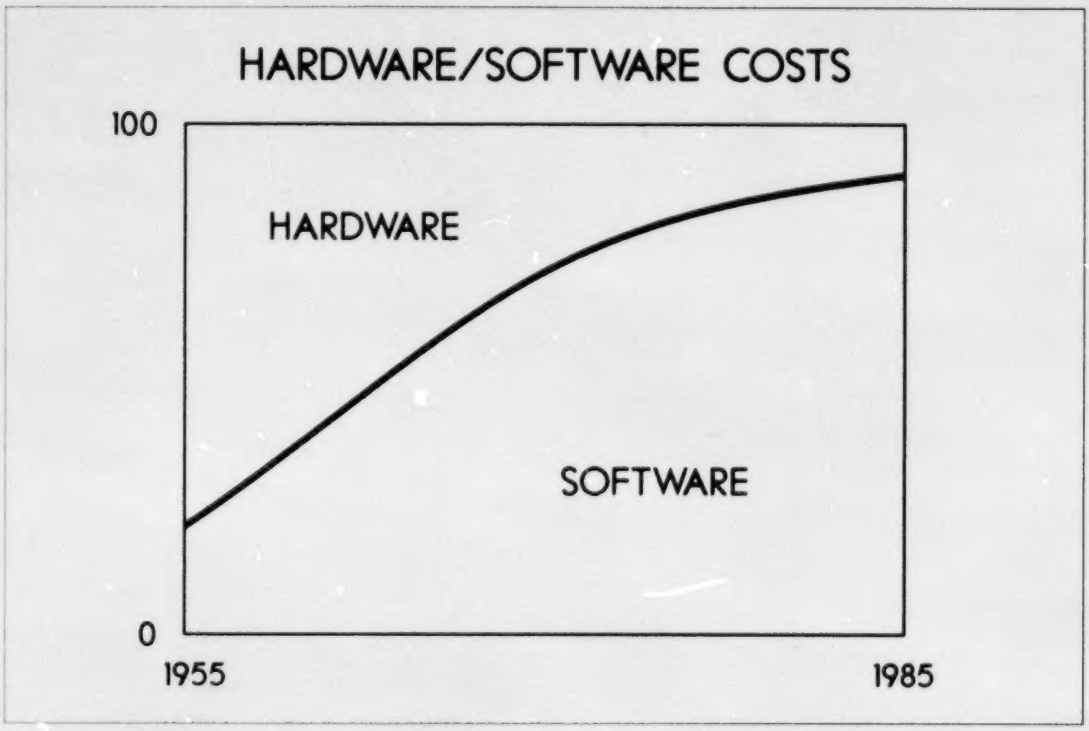

Figure 46. Simple, stark version of graph for a slide presentation. (Real slide is in color)

The report version, in black and white, has more information, more labeling, tick marks, grid lines, footnotes, etc. It tells a whole story on its own - but the audience can study the graph at leisure.

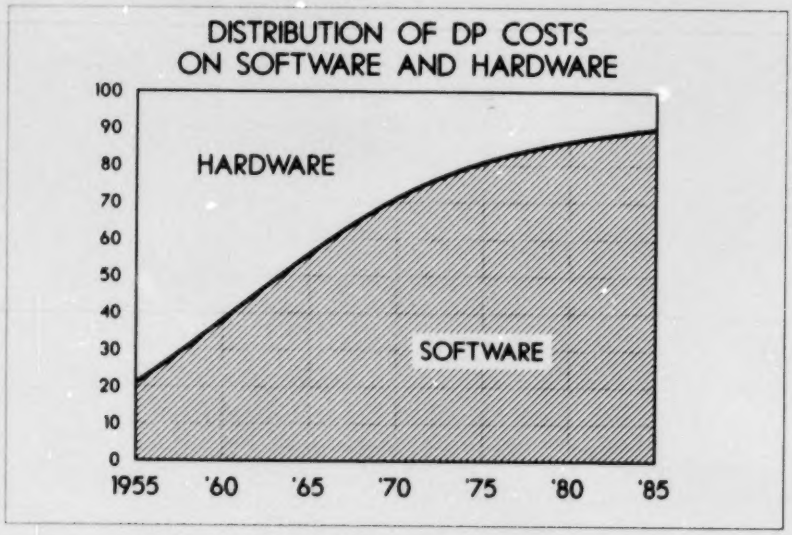

Figure 47. Report version of graph has more detail and annotation, different style

But even for a report, we must not go too far as in the graph below. The graph should not become a masterpiece in its own right, overshadowing the message. Do we really need to state the source so fully, including a page reference? Wouldn't we be better off with two graphs, one showing the distribution between hardware and software, another showing the division of software costs into development and maintenance?

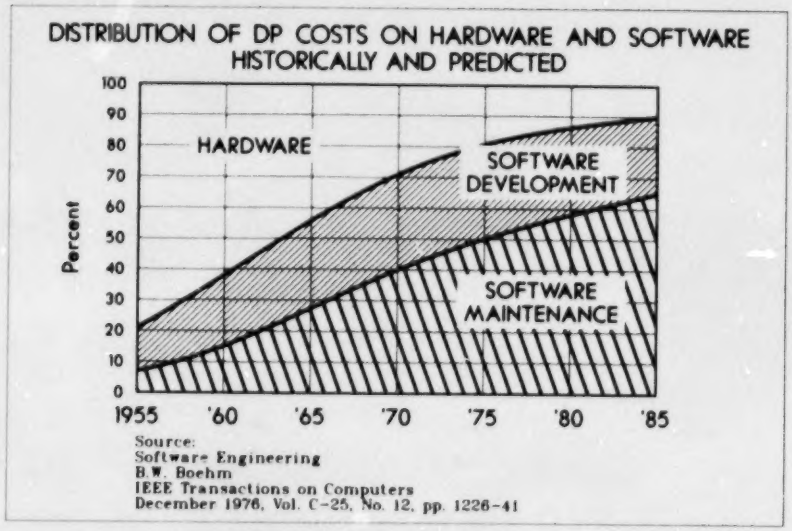

Figure 48. Overdone graph

We should remember the classical psychological law of "The Magic Number 7 plus/minus 2". Psychological experiments have shown conclusively that the human mind can handle seven, more or less, things at the same time. This result is independent of the size or complexity of the "things:" cars coming into an intersection, dials on a control panel, kids running around, items on a slide, segments in a pie chart.

The variation between 5 and 9 depends on training, fatigue, etc. This is why advice about slides presentations, where the state of mind of the audience is somewhat uncertain, is more conservative ("six items on a text slide, five segments in a pie chart") than what we might want to do in a text book, which people can be expected to lay down when they get tired.

Some researchers have come up with elaborate formulas governing minimum character size as a function of the size of the audience or the dimensions of the auditorium. Such formulas, although precise, well founded, and most valuable, are very hard to remember. A simpler approach is the classical "if a slide can not be read at arm's length without magnification, it can not be read at any distance with any magnification."

The basic rules for any medium, but particularly for presentation aids, are thus:

- DO NOT OVERANNOTATE
- DO NOT INCLUDE ALL THE INFORMATION

To this could be added, DO NOT BE TOO CLEVER. The graph below, part of a slide presentation, states a very important point, and does it in a very clever fashion. But when the author saw the graph, the message didn't penetrate until several slides later, after some heavy pondering; and those slides were completely lost, of course.

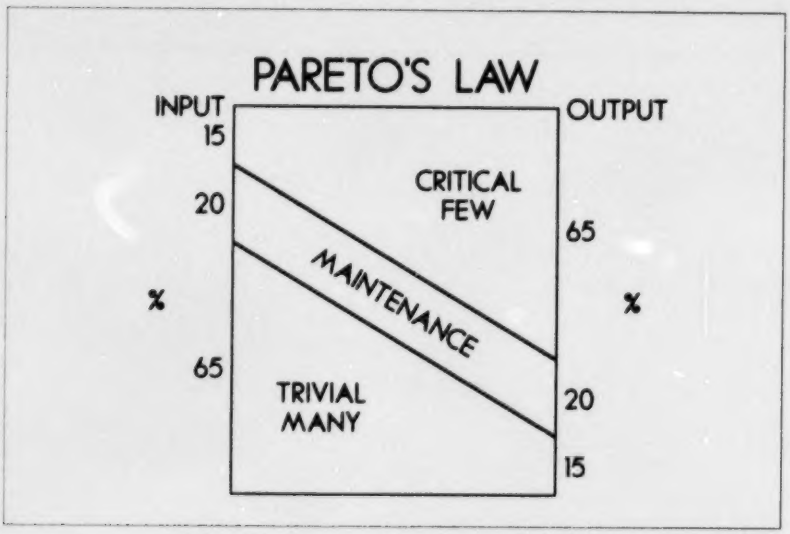

Figure 49. Very neat, and especially effective in color - but what does it say?

CONCLUSION

"Artistry" is a word which to most computer users brings up images of black magic. But there is nothing mystical about good data representation. We can learn these skills - and we should. Few of us can afford to spend a lot of effort on research, planning, development, production, whatever - only to lose out on a poor presentation.

Understanding is the key. Practice is necessary. But for amateurs in graphic representation, the best rule is probably

STUDY THE VISUAL EFFECT - DON'T THEORIZE

The effect on the visual processing, on the right brain, of a particular arrangement, color combination, or pattern sequence, is virtually impossible to predict. We must learn to drop our preconceptions, and view the graphical alternatives as an unprepared onlooker would see them. We must gauge the immediate visual effect.

We believe that the computer based tools must be designed to allow this kind of experimentation. While we (our left brains) cannot always say beforehand which graph type is best, we (our right brains) usually recognize a good graph when we see it. Allowing economic experimentation is one advantage computer graphics has over an artist. Few of us have the guts to ask the art department to draw a dozen different graphs, and let us choose which one we like. With a computer we can, and should.

And in a few years perhaps we can tell the computer the data, the prejudices of the audience, and the intended effect, and ask it to design an effective graph for us.

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Ganthiers-Villears

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